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Influence of Heterosis and Plane of Nutrition on Rate and Economy of Gains, Digestion and Carcass Composition of Pigs

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K. E. GREGORY[1] AND G. E. DICKERSON

INTRODUCTION

The phenomena of heterosis or hybrid vigor has long been utilized by commercial swine producers. Previous research by Winters, *et al.* (1935),[2] Lush, *et al.* (1939), and by others has demonstrated adequately that crossbreeding improves most economic characters and markedly increases over-all performance in swine. In recent years, much of the emphasis in swine breeding research has been placed on developing systems of breeding intended to enhance and to further exploit hybrid vigor for commercial swine production. To use hybrid vigor most effectively, the fundamental nature of its effects on economically important traits must be understood clearly. Results by Dickerson, *et al.* (1946, 1947) for single crosses of inbred lines showed a marked increase in feed consumption and rate of gain, but with little improvement in economy of gain or change in carcass composition. These results raise fundamental questions as to the nature of the heterosis effects in energy utilization.

Any attempt to study heterosis effects, independent of differences in feed consumption, involves restricting the appetite of crosses. Ellis and Zeller (1934), and Winters, *et al.* (1949) have shown that limited-feeding reduces the fat content of the carcass and the feed required per pound of gain in weight. In order to separate effects of heterosis from those of limited-feeding, it was necessary to measure the effects of both in the present experiment.

The primary purpose of this study was to learn how heterosis affects rate and economy of gain and carcass composition under full-feeding and when feed intake of crosses is restricted to that of the parent strains. However, the study does provide additional information on the general effects of limited-feeding and new information on the variation in response among strains and their crosses.

Acknowledgment—The authors gratefully acknowledge the assistance and cooperation of Professors C. W. Gehrke, J. F. Lasley, D. T. Mayer and L. A. Weaver, and of C. F. Craig, Swine Herdsman, during this investigation. This work was conducted as part of the Missouri project of the Regional Swine Breeding Laboratory, with the support and encouragement of Director W. A. Craft.

[1]This report includes much of the material presented by the senior author as a dissertation for the Doctor of Philosophy degree in August, 1951. The senior author is now Associate Animal Breeder at Alabama Polytechnic Institute, Auburn, Ala.

[2]References are to literature cited, a bibliography of which will be found on pages 41 and 42.

MATERIALS AND METHODS

A. Experimental Animals

The experimental animals used in this study were derived from three inbred lines of swine that were maintained at this station in cooperation with the Regional Swine Breeding Laboratory, and from the outbred Durocs that were maintained as a part of the College herd. The inbred lines represented were two inbred lines of Poland Chinas (II and VI) and one of Hampshires (V). Line II has been maintained as a closed line since 1938; however, the rate of inbreeding has been rather slow. The coefficient of inbreeding (Wright, 1921) of the pigs in this line was about 44 per cent. Lines V and VI have also been developed by a moderate system of inbreeding and have been maintained as closed lines since 1944. The inbreeding coefficients of the pigs from Lines V and VI were about 40 and 34 per cent, respectively.

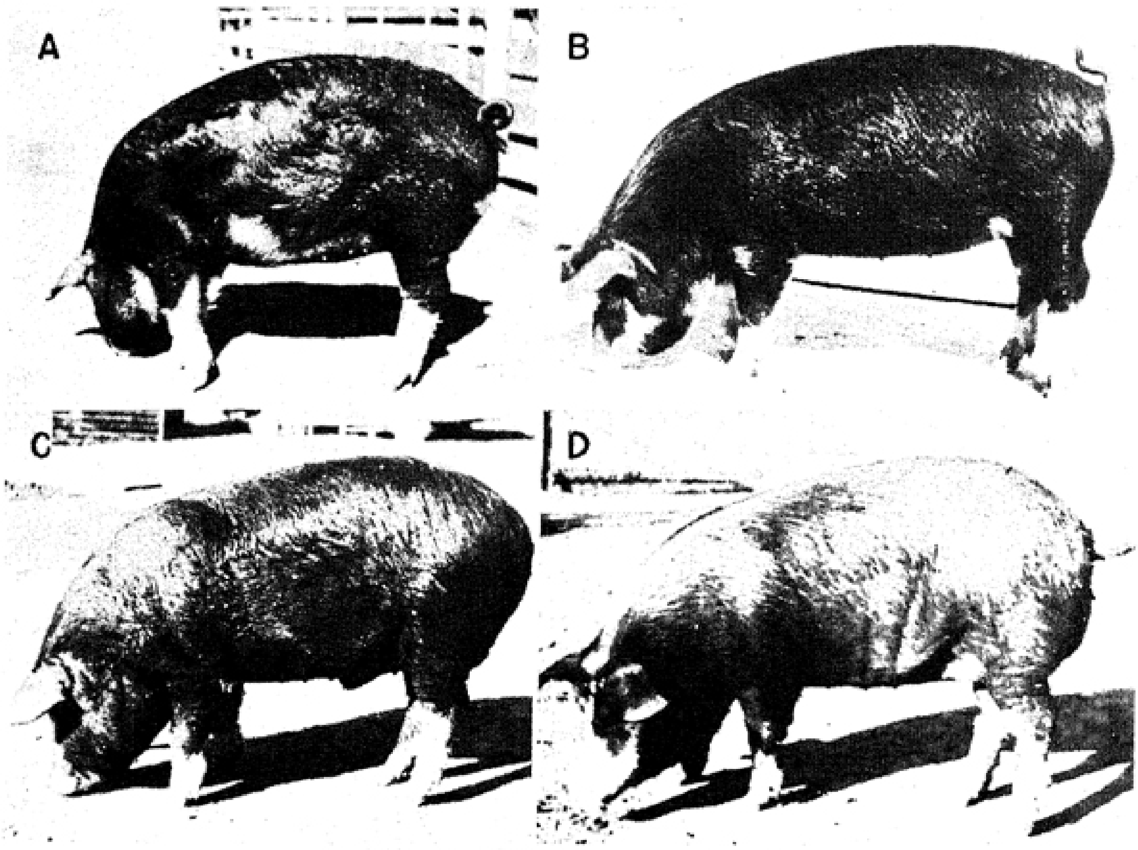
Selection for performance traits has been practiced in the inbred lines since their origin. The performance characters that have received primary consideration are 154-day weight and litter size, and weight at weaning. The outbred Durocs have likewise been selected for these traits; however, unrelated Duroc boars have been introduced periodically and the selection procedures have been less systematic than in the inbred lines.

The 11 breeding groups represented in this experiment were pigs from the three inbred lines and their three crosses, the three inbred lines top-crossed on Durocs, outbred Durocs and II x VI Poland China gilts mated to Duroc boars (Figs. 1, 2, 3).

B. Methods

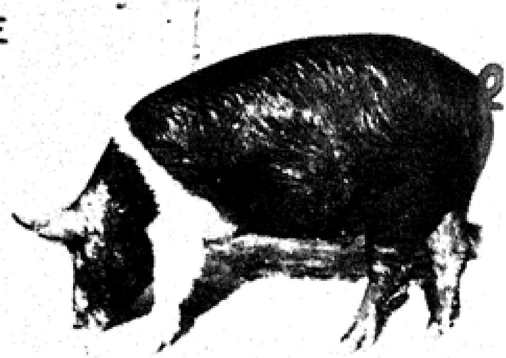
Experimental Plan. The major objective of this experiment was to determine the nature of the heterosis effect obtained from crossing inbred lines and from top-crossing inbred Poland China and Hampshire lines on outbred Durocs. Previous work at this station[3] and by Dickerson, *et al.* (1946), and Sierk and Winters (1951) had shown that crosses eat more and grow more rapidly than the parental inbreds, but require nearly as much feed per unit of gain in weight and produce carcasses of similar composition. These results naturally lead to the question: Would the advantage of crosses over parental inbreds disappear if crosses were limited to the same feed intake as the inbreds?

Brody and Kibler (1944) have shown that basal metabolism in pigs tends to vary directly with body weight up to puberty but that thereafter it varies with surface area or with the .6 power of live weight. The energy lost through activity varies directly with body weight if the movement of the different weight animals is the same (Brody, 1945). These results indicate that maintenance requirements vary directly with body weight in pigs before they reach puberty, except as there may be inherent differences between inbreds and crosses or between strains or individuals. For this reason, the limited-fed crosses were fed



A & B - Line II Poland China gilts, No. 390 full-fed and No. 114 limited-fed.

C & D - Line VI Poland China, No. 95 fullfed barrow and No. 401 limited-fed gilt.



E - Line V Hampshire, No. 133 limited-fed gilt.

F & G - College Durocs, No. 459-1 full-fed barrow and No. 445 limited-fed gilt.

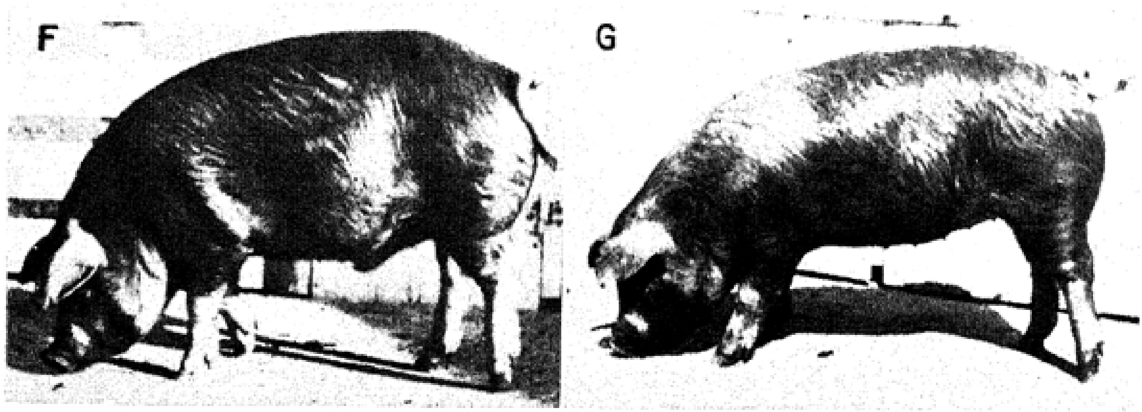


Figure 1.--Individuals from the four parent lines at a live weight of approximately 205 pounds.

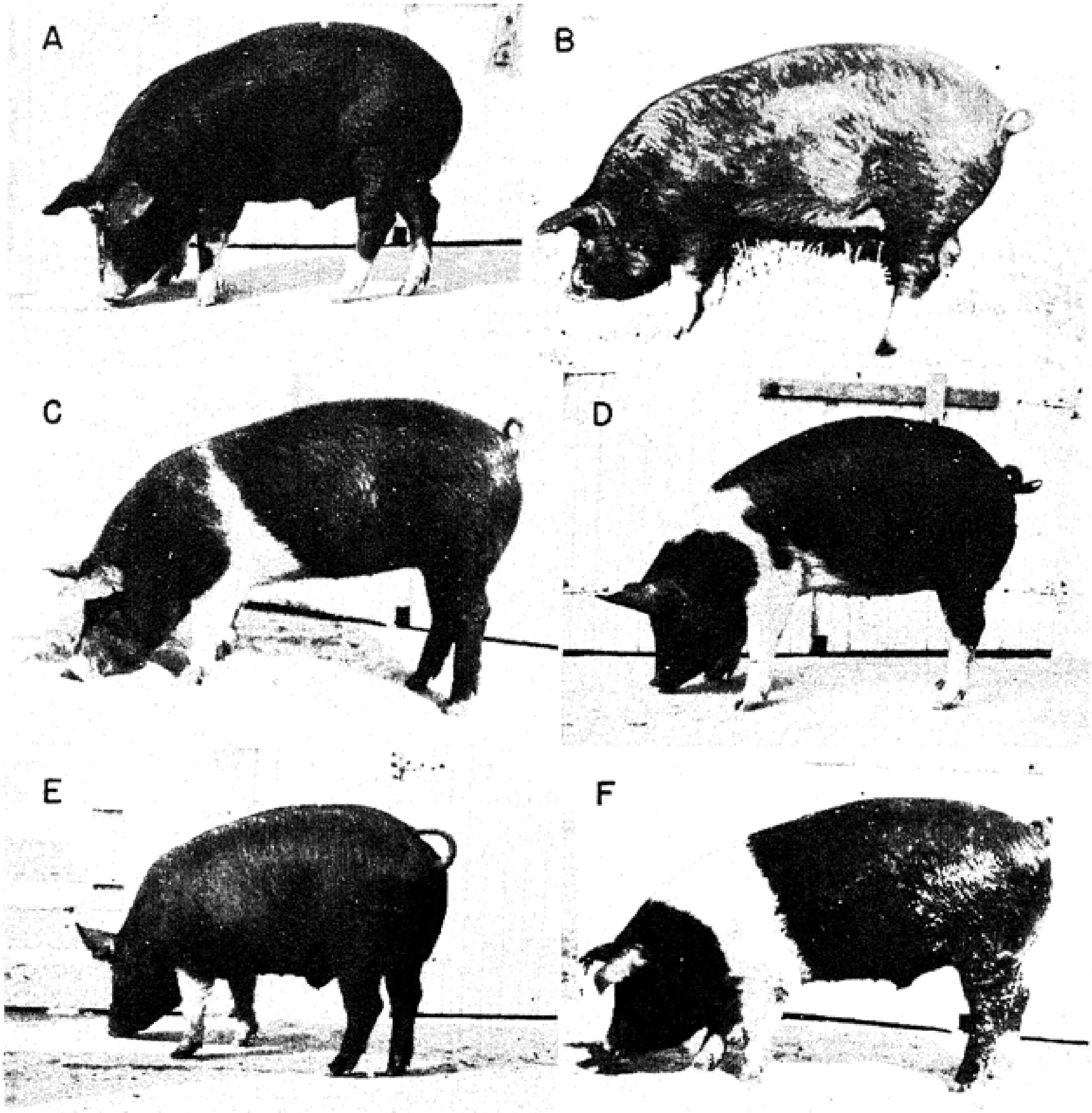


Figure 2.--Individuals from the three linecrosses at live weights of approximately 205 pounds.

A & B - Poland (II x VI). No. 431 full-fed barrow and No. 244 limited-fed gilt.

C & D - Poland-Hampshire (VI x V). No. 510 full-fed gilt and No. 346 limited-fed gilt.

E & F - Poland-Hampshire (VI x V). No. 569 full-fed barrow and No. 214 limited-fed barrow.

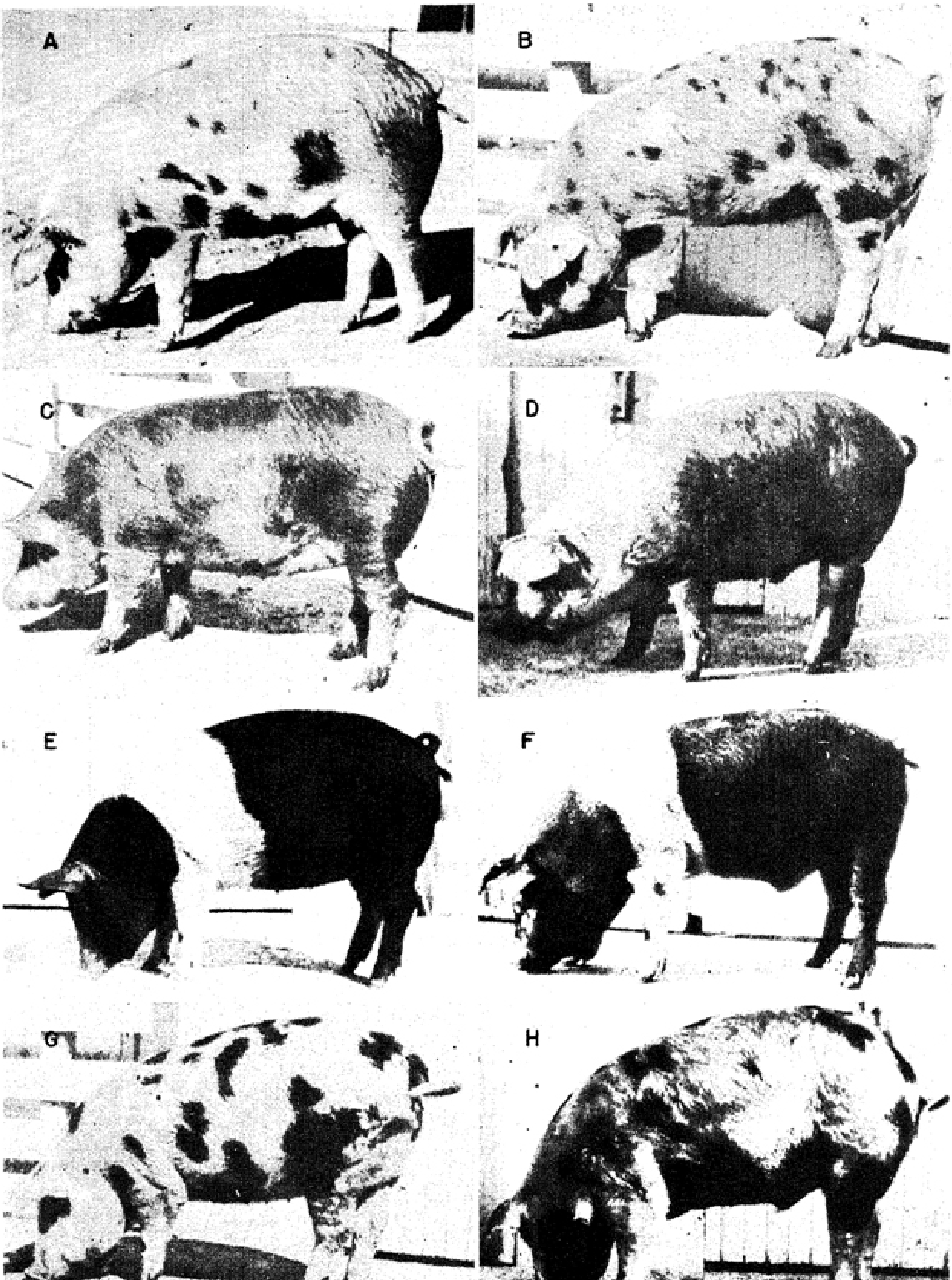


Figure 3.--Individuals from the crosses with non-inbred Durocs, at live weights of approximately 205 pounds.

A & B - Poland-Duroc (II x D). No. 85 full-fed gilt and litter-mate No. 83 limited-fed gilt.
C & D - Poland-Duroc (VI x D). No. 250 full-fed gilt and No. 109-1 limited-fed barrow.
E & F - Hampshire-Duroc (V x D). No. 460 full-fed gilt and No. 484 limited-fed barrow.
G & H - Duroc-Poland (D x I · VI). No. 311 full-fed gilt and No. 35 limited-fed barrow.

at the same level of intake (on a unit weight basis) as the full-fed inbreds of the parental lines, and the limited-fed inbreds were fed the same percentage of that for full-fed inbreds as the limited-fed crosses were fed relative to the full-fed crosses.

Four litters were farrowed in each group and 16 representative pigs were selected from each group at weaning (56 days). Each group was divided into two lots of eight pigs, equalizing sex, litter, and initial weight as well as possible. One lot was full-fed and the other was limited-fed. The feed intake of the limited-fed lots was regulated by the feed intake for the full-fed lots, on a unit live weight basis, as follows:

Breeding	Feed Intake per Unit of Live Weight (Adjusted Weekly)
Line II Inbred Poland China	Full-fed Inbred Line II x Ratio $\frac{\text{Ltd.}}{\text{Full}}$ for Line II crosses
Line VI Inbred Poland China	Full-fed Inbred Line VI x Ratio $\frac{\text{Ltd.}}{\text{Full}}$ for Line VI crosses
Line V Inbred Hampshire	Full-fed Inbred Line V x Ratio $\frac{\text{Ltd.}}{\text{Full}}$ for Line V crosses.
II x VI	Average of full-fed II and VI lots
II x V	Average of full-fed II and V lots
V x VI	Average of full-fed V and VI lots
II x Duroc	Same as full-fed Line II lot
VI x Duroc	Same as for full-fed Line VI lot
V x Duroc	Same as for full-fed Line V lot
Duroc x (II x VI)	Average of full-fed Line II and VI lots
Duroc	Average of full-fed II, VI, and V inbred lots

Feeding and Management. The male pigs used in this study were castrated when about 21 days old. All pigs were immunized for hog cholera and for erysipelas when about 56 days old. Both the live virus and serum were used for cholera, and antiserum was used for erysipelas.

The pigs were weaned at 56 days of age and put on test in concrete-floored lots where they were kept until they reached market weight of approximately 205 pounds. The pigs were weighed at weekly intervals and the feed intakes of the limited-fed pigs were adjusted according to feed consumption of full-fed pigs during the preceding week.

The ration used throughout the experiment is presented in Table 1. All of the ingredients were ground in a single mixed ration. A mineral supplement consisting of equal parts of steamed bone meal, sodium chloride and ground limestone was fed, free choice, to all lots throughout the experiment. Calcium pantothenate was added to the ration for a 49-day period to alleviate a pantothenic acid deficiency that had developed. On the basis of previous experience with similar rations, it was thought at the initiation of the experiment that the ration used should be adequate to promote normal growth. However, this deficiency symptom was manifested and it is possible that the ration was deficient in other factors.

TABLE 1 -- RATIONS FED BY PERIODS

Days	% Corn Yellow (No. 2)	% Tankage (60% Protein)	% Soybean Oil Meal (Solvent Process, 43% Protein)	% Dehydrated Alfalfa Meal (20% Protein)	Calcium Pantothenate
45	67	12.38	12.37	8.25	
52[1]	75	9.38	9.37	6.25	
49[2]	75	9.38	9.37	6.25	4 Mgm/lb.
78	75	6.25	12.50	6.25	

1/ Ration fed during first digestion trial.
2/ Ration fed during second digestion trial.

Digestion Trials. Digestion trials using the "chromium oxide ratio technique" were conducted for all 22 lots at two periods during the trial. Trials were made when the pigs were about four months old and when about 5½ months old.

Ratio techniques for the determination of digestibility have been used fairly extensively in recent years. The major advantages of a ratio technique over the standard total-collection procedures are: (1) the saving in time and materials, (2) normal conditions of activity and (3) larger numbers of animals to reduce sampling errors from variation between animals.

The suitability of any reference substance for the determination of digestibility is based primarily on the completeness of its passage through the digestive tract of the animal and upon the ease and accuracy of its quantitative determination in feed and feces. Kane, *et al.* (1949, 1950a, 1950b), and Barnicoat (1945-1946) have shown that chromium oxide can be used satisfactorily as a reference substance in digestibility studies. If the percentage of chromium oxide in the feed and feces and the percentage of any particular nutrient in the feed and feces is known, the digestibility of that nutrient can be calculated by the following formula:

$$\text{Digestibility } \% = 100 - 100 \frac{\% \ Cr_2O_3 \text{ in feed}}{\% \ Cr_2O_3 \text{ in feces}} \times \frac{\% \text{ Nutrient in feces}}{\% \text{ Nutrient in feed}}$$

In this study one-half of one per cent of chromium oxide (Cr_2O_3) was thoroughly mixed with the finely ground ration. The ration containing the chromium oxide was fed over an eight-day period and samples were taken from the fecal material voided during the last five days. Daily samples of approximately two pounds of fresh feces were taken from each breeding group at both feeding levels for the five-day period. The time of sampling was varied from day to day in order to minimize sampling errors that might result from collecting at a particular time during the day. Kane, *et al.* (1950a) have concluded that the time of sampling and the number of samples taken are important factors when the ratio technique is used in digestion trials with cattle. It is thought that the methods of sampling used in this investigation were adequate to get a representative sample of the total feces voided during the trials. Feed samples were taken daily over the five-day period and analyses were made of these individual samples to check the maintenance of uniformity of the chromium oxide-feed mixture.

After collection, the fecal samples were sealed in cellophane bags and stored at +10°F. until they were analyzed. The samples taken over the five-day collection period were thoroughly mixed and samples of approximately one pound were submitted to the Department of Agricultural Chemistry for analyses. Standard analytical procedures were used for the determination of water, protein, ether extract, ash and crude fiber. The method used for the determination of chromium oxide has been reported by Gehrke, *et al.* (1950).

Slaughter and Carcass Data. The hogs were removed from the experiment at weekly intervals, as soon as they had reached a live weight of at least 200 pounds. They were trucked directly to a local packing plant and slaughtered immediately after arrival. They were dressed Packer Style (head off, jowl and feet on and leaf fat and kidneys in) and held in a chill room at approximately 35°F. for a 24-hour period.

The chilled carcasses then were removed from the chill room, weighed and cut into the various wholesale cuts. One man did all of the cutting in a reasonably uniform manner for all pigs. The shoulders were cut between the second and third ribs and the hams were cut about two inches anterior to the aitch bone (symphysis pubis) in a plane perpendicular to the "shank" bone. The hams and the shoulders were "skinned," the bellies were squared and the teat line removed. Not more than 1/4 inch of fat was left on any part of the loin. The hind feet were removed just above the hock joint and the front feet were separated from the shoulder just above the knee joint.

Weights of the skinned hams, skinned shoulders, trimmed loins, lean trimmings, bellies, backfat, leaf fat, fat trimmings, and "bone" were taken. The "bone" weight included the feet, spare ribs, neck bones and kidneys. The skin was removed from the lean trimmings and weighed with the fat trimmings.

The gross carcass measurements taken were: body length from the anterior edge of the first rib to the anterior edge of the aitch bone; length of the hind leg from anterior edge of the aitch bone to coronary band of the hoof; ham length from the anterior edge of the aitch bone to the hock joint; and ham circumference midway between the anterior edge of the aitch bone and the hock joint. Thickness of backfat was measured opposite first rib, last rib, last lumbar vertebra and on the outer face of the unskinned ham directly opposite the ilium. The loin was cut at the last rib and the width and depth of the cross-section of the longissimus dorsi muscle were measured. Width was measured at the widest point and the depth was measured at the deepest point in a plane perpendicular to the width measurement. Similar width and depth measurements were taken of the cross-section of the ham muscle on the butt of the un-

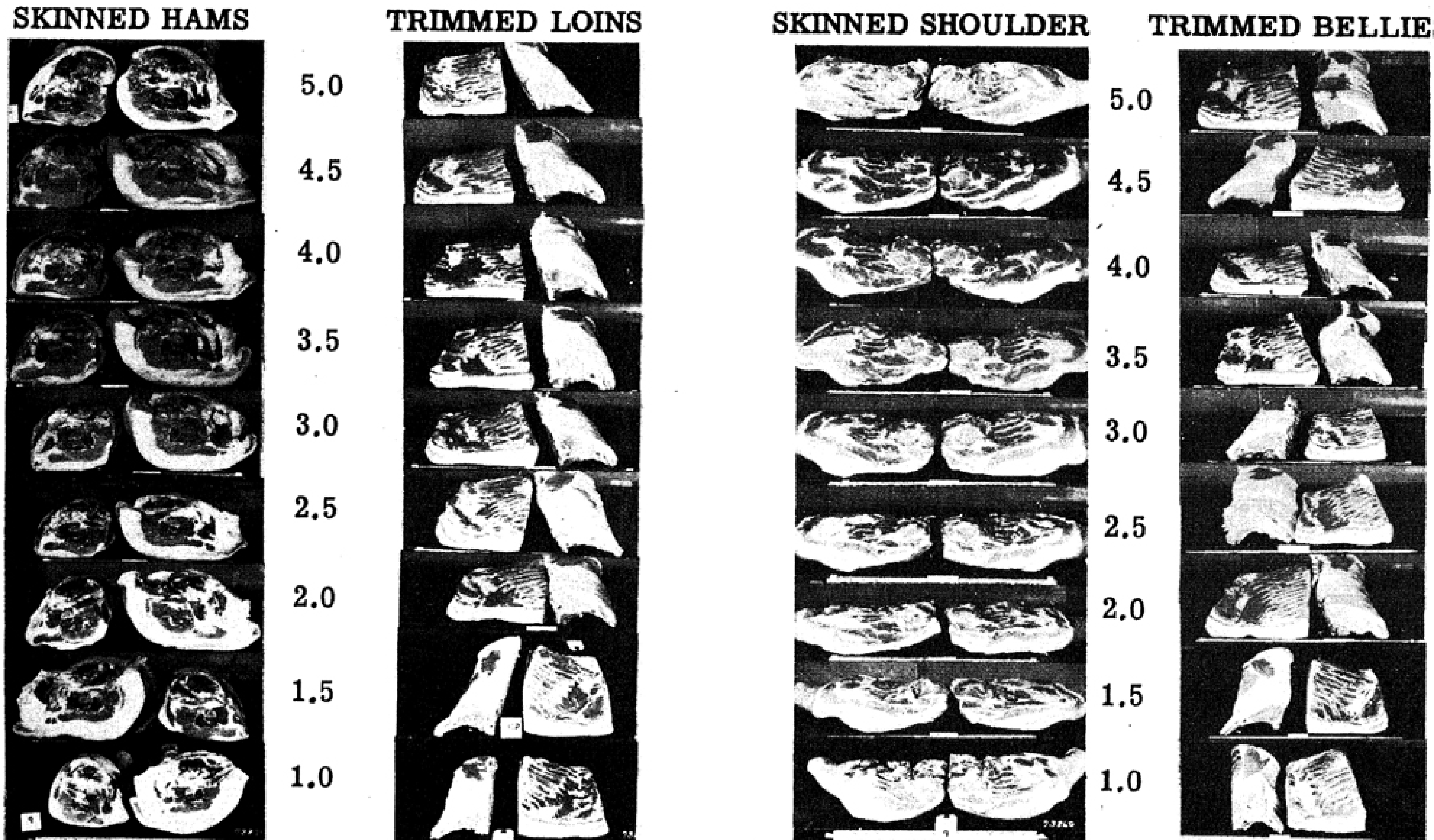


Figure 4.--Graded series of photographs indicating composition of wholesale cuts corresponding to the scores given for desirability

trimmed ham. The bottom edge of the ilium and the edge of the fat on ham were reference points for the depth measurement which was taken in a plane perpendicular to the cutting table when the ham lay with aitch bone up and fat side next to the table. The width measurement was taken at the level of the ilium in a plane parallel to the cutting table. Thickness of trimmed belly was measured in the flank pocket.

The trimmed hams, loins, shoulders and bellies were scored according to desirability of composition, from the consumers viewpoint (see Fig. 4). The major consideration in scoring the trimmed cuts was the amount of muscle in relation to fat and bone. In scoring the bellies, some attention was given to thickness and especially to uniformity of thickness, but the major emphasis was placed on composition. The muscle dimensions were used as a partial guide in scoring the hams and loins. Additional attention was given to the muscular development at both ends of the loin and to the shape, plumpness and thickness of remaining fat on the trimmed ham.

It is realized that the scoring for desirability of the wholesale cuts was subjective in nature. However, they do describe differences in proportion of lean in the cuts that are highly important to purchasers of pork cuts. There was little variation in the scoring between weeks, since the same personnel did all of the scoring and the agreement between those doing the scoring was remarkably high.

C. Analysis of Data

The data were divided into the following categories for analysis: (1) digestibility of ration; (2) rate and economy of gains; (3) net carcass merit; (4) conformation and muscular development, and (5) fatness of carcass.

1. **Digestibility of Ration.** Digestibility was calculated separately for protein, fat, nitrogen-free extract, and total dry-matter in the ration.

2. **Rate and Economy of Gain.** The major items in this category were average daily gain, feed required per hundred pounds of gain and the age when the animals reached market weight or age when the experiment was terminated.

3. **Carcass Merit.** The items in this grouping included dressing per cent, equivalent yield of loin as percentage of chilled carcass weight and filled live weight, both unadjusted and adjusted for quality, and weighted mean score for consumer desirability of ham, loin, shoulder and belly. Dressing per cent was calculated from chilled carcass weight and filled live weight.

The values used in expressing the yield of all cuts as equivalent yield of trimmed loin were: 1.0 for trimmed loin, 0.9 for skinned ham, 0.8 for skinned shoulder and trimmed belly, 0.7 for lean trimmings, 0.2 for backfat, leaf fat and fat trimmings and 0.1 for "bone," including spare ribs, neck bones, feet, tail and kidneys. These approximate relative values for the various cuts were based on average Chicago wholesale prices for 1937 to 1947, considering the method of cutting used in the local packing plant where the data were collected. The actual prices of spare ribs and feet would make the items lumped under "bone" worth somewhat more than .1 as much as loin, but variation in yield of "bone" is small relative to other cuts.

The scores for desirability of the ham, loin, shoulder and belly cuts were used in adjusting the equivalent yield of trimmed loin to a standard basis for quality. The scores for these cuts ranged from 1 to 5, with 1 being the least desirable and 5 the most desirable. The factors used in adjusting "Loin Equivalent" for scores of the cuts were: 1 = 0.8, 2 = 0.9, 3 = 1.0, 4= 1.1 and 5 = 1.2. Figure 4 shows the range in composition of each cut corresponding to the scores given.

4. **Conformation and Muscling.** The items studied in this category were body length, leg length, estimated yield of lean as percentage of chilled carcass weight, dimensions of cross-section of loin muscle at last rib and of muscle on ham butt, yield of lean cuts and yield of bone as percentage of chilled carcass weight.

The regression equation developed by McMeekan (1941) was used in estimating yield of lean as percentage of the chilled carcass weight, from dimensions of the loin muscle cross-section. The products of width and depth for the ham and for the loin muscle were used to approximate the surface area of these muscle cross-sections.

5. **Fatness of Carcass.** The items selected to be most indicative of fatness were: mean backfat thickness, thickness of fat on ham, belly thickness in flank pocket, and yield of fat cuts as percentage of chilled carcass weight. Two methods were used in estimating the per cent fat in the edible portion of the carcass. The total percentage of fat in the chilled carcass was also estimated.

The regression equation developed by Hankins and Ellis (1934) from hogs of intermediate type was used to estimate yield of fat in the edible portion of the carcass from the mean backfat thickness. The regression equation developed by Warner, *et al.* (1934) also was used to estimate the percentage of fat in the edible portion of the carcass from the percentage of trimmed belly and backfat in the chilled carcass. The regression equation developed by McMeekan (1941) was used to estimate the percentage of fat in the chilled carcass from the thickness of backfat at the last rib. Any one of these regression equations is likely to yield a slightly biased estimate of the absolute percentage of fat in the carcasses from the present study, because of differences in the mean or range of live weight at slaughter or in the composition typical of the populations studied. However, they serve admirably to indicate small differences in composition between carcasses from different feeding treatments or breeding groups. McMeekan's pigs were slaughtered at the same weight used by us, but were a little less fat and varied more in fatness due to the extreme variation in the feeding levels he used. Pigs studied by Hankins and Ellis averaged about 20 pounds heavier at slaughter and varied much more in slaughter weight than those in the present study.

Tests of significance for the general effects of feeding level and breeding group on each item studied were based on an analysis of variance (Snedecor, 1946). An analysis of variance based on weighted mean differences was used to determine significance of the various paired comparisons made to study the nature of the heterosis effects.

RESULTS AND DISCUSSION

A. Effects of Limited Feeding

The unique feature of the present experiment was a comparison of line-crosses and topcrosses with parent inbred lines at the same daily level of feed consumption per unit of live weight. This involved restricting the natural appetite of most crosses by 10 to 20 per cent. In order to differentiate the effects on performance of restricting feed intake from those of heterosis, it seemed desirable to consider first the general effects of limited feeding.

Digestibility of Ration (Table 2 and Appendix Tables 21, 22 and 23).

TABLE 2 -- DIGESTIBILITY OF RATION USING "CHROMIUM OXIDE RATIO TECHNIQUE" AVERAGE OF TWO TRIALS BY FEEDING LEVELS IN EACH LINE AND CROSS

Breeding	Feeding Level	Protein	Crude Fiber	Fat	N.F.E.	Dry Matter
II	Full	74.06	24.08	70.54	89.36	79.34
	Ltd.	72.26	13.85	62.82	88.78	77.30
	Mean	73.16	18.97	66.68	89.07	78.32
VI	Full	71.44	27.25	56.21	89.85	78.44
	Ltd.	71.28	26.32	55.14	90.97	79.09
	Mean	71.36	26.79	55.68	90.41	78.76
V	Full	71.99	26.43	62.78	89.95	78.98
	Ltd.	70.46	22.14	55.55	89.97	77.90
	Mean	71.22	24.28	59.16	89.96	78.44
II x VI	Full	70.82	24.96	66.16	88.89	77.70
	Ltd.	71.73	26.62	57.77	90.31	78.79
	Mean	71.27	25.79	61.97	89.60	78.25
II x V	Full	73.05	29.31	68.65	90.11	79.74
	Ltd.	72.24	14.71	67.13	88.49	77.04
	Mean	72.64	22.01	67.89	89.30	78.39
V x VI	Full	73.45	34.80	63.38	91.17	80.64
	Ltd.	71.87	24.03	58.43	90.36	78.64
	Mean	72.66	29.41	60.91	90.77	79.64
II x D	Full	73.82	29.98	69.40	90.08	79.89
	Ltd.	73.09	19.45	65.18	90.13	79.05
	Mean	73.45	24.72	67.29	90.10	79.47
VI x D	Full	70.08	23.99	55.43	90.54	78.65
	Ltd.	74.06	23.74	66.87	89.55	79.00
	Mean	72.07	23.87	61.15	90.05	78.82
V x D	Full	71.11	30.40	56.55	90.83	79.29
	Ltd.	71.68	15.15	59.10	89.71	77.66
	Mean	71.40	22.77	57.83	90.27	78.48
D x (IIxVI)	Full	72.31	27.24	67.68	89.71	79.19
	Ltd.	74.36	24.97	67.09	90.03	79.40
	Mean	73.33	26.11	67.38	89.87	79.30
Duroc	Full	72.83	25.74	58.23	89.80	78.80
	Ltd.	74.22	20.88	66.84	89.95	79.34
	Mean	73.53	23.31	62.53	89.88	79.07
Means	Full	72.27	27.65	63.18	90.03	79.15
	Ltd.	72.48	21.08**	61.99	89.84	78.47

** P ≤ .01

Analysis of the pooled data from the two digestion trials indicated no significant difference between feeding levels in digestibility of dry matter. However, there was a highly significant difference between feeding levels in the way digestibility of dry matter changed between trials. Also, digestibility of crude fiber was significantly lower for the limited-fed lots. It is believed that a weakness in experimental technique may have accounted for these differences, since the limited-fed pigs were detected eating lespedeza stems from their bedding material during the second digestion trial. The bedding material during this trial consisted of lespedeza stems and wheat straw with a very high crude fiber content. Any appreciable consumption of it would naturally increase the proportion of crude fiber in the feces, thus lowering the calculated digestibility for this component of the ration. The reduction in calculated digestibility of crude fiber for the limited-fed lots tended to be larger in those breeding groups where the feed restriction of the limited-fed pigs was the greatest, presumably because of higher consumption of crude fiber from the lespedeza stems.

Wheat straw alone was used for bedding during the first digestion trial and the pigs were not detected consuming any of this material during this period. The results of this first trial indicated small but non-significant increases in digestibility of protein, fiber, fat and N.F.E. in limited-fed lots. The advantage in apparent digestibility of total dry matter was small, because calculated digestibility of ash was lower for the limited-fed lots (21.2 vs. 28.9 per cent). The mineral supplement was fed separately and was not included in the analysis of feed. Thus greater consumption of mineral supplement by the limited-fed lots would increase ash content of feces, reducing calculated digestibility of ash.

In the second trial, the extra fiber intake from consumption of the lespedeza stems by the limited-fed pigs should have increased content of fiber and reduced that of other constituents in the feces. If the additional fiber had no actual adverse effect on digestibility of other constituents, it would have increased calculated digestibility of other constituents. Digestibility of all constituents was actually lower for the limited-fed lots in the second trial. This reversal in direction of the effect of limited feeding on digestibility between the two trials was highly significant. It suggests that the consumption of lespedeza from the bedding actually reduced digestibility of the ration in limited-fed lots.

Rate and Economy of Gains (Table 3 and Appendix Table 24). The limited-fed pigs consumed only about 87 per cent as much feed daily per unit of live weight, gained about 0.1 pound less per day and required 14 days longer to reach market weight, compared to the full-fed pigs. Feed required per hundred pounds of gain was 28 pounds less for the limited-fed pigs. These differences were highly significant.

Carcass Merit (Table 4 and Appendix Table 24). The limited-fed pigs dressed about one per cent lower among the inbreds and two to three per cent

TABLE 3 -- GAINS, FEED CONSUMPTION AND UTILIZATION, BY FEEDING LEVELS IN EACH LINE AND CROSS

Breeding Group	Feed Level	Inbr. %	No. Pigs St'd	No. Pigs End	Init. Wt./ Pig	Fin. Wt./ Pig	Gain /Day /Pig (pounds)	Feed Cons. /Cwt. /Day	Feed Req. /Cwt. Gain	Age Off Expt. (days)
Line II	Full	43.18	8	6	29.2	202	.94	3.98	380	211
	Ltd.	43.18	8	8	30.4	205	1.06	3.72	336	224
Line VI	Full	32.30	7	7	30.7	207	1.08	4.65	424	219
	Ltd.	35.87	7	6	30.4	206	1.03	4.32	394	224
Line V	Full	40.85	8	5	25.5	194	.70	3.89	453	257
	Ltd.	42.31	8	6‡	25.9	154	.56	3.64	452	257
II x VI	Full	9.00	8	6	35.1	205	.97	4.20	408	200
	Ltd.	9.00	8	6	35.2	207	.88	3.87	424	230
II x V	Full		8	8	36.1	207	1.26	4.33	358	192
	Ltd.		8	8	36.2	207	1.12	3.89	343	208
V x VI	Full		8	8	32.4	209	1.32	4.92	374	186
	Ltd.		8	8	33.4	209	1.09	4.21	372	213
II x D	Full		8	8	31.1	207	1.14	4.69	405	211
	Ltd.		8	8	30.8	208	1.13	3.96	330	213
VI x D	Full		8	8	32.1	207	1.36	5.07	369	184
	Ltd.		8	8	32.1	212	1.30	4.51	344	195
V x D	Full		8	8	28.9	204	1.22	4.64	361	199
	Ltd.		8	8	29.6	202	1.02	3.84	344	224
D x (II x VI)	Full		8	8	32.2	208	1.28	5.27	413	192
	Ltd.		8	8	31.6	210	1.17	4.23	351	208
Duroc	Full		8	8	30.6	205	1.27	5.18	394	188
	Ltd.		8	8	31.1	210	1.18	4.07	336	208
Means	Full		87	80	31.3	205	1.14	4.62	394	204
	Ltd.		87	82	31.5	203	1.05**	4.02	366**	218**
Std. Err. Mean Diff.							.02		8.56	2.63

‡ Three pigs from the Line V limited-fed lot were too small to be used in the carcass study when the experiment was terminated.
** $P \leq .01$

lower among the non-inbred groups. Both the average effect of feeding level and the difference in its effect between inbred and non-inbred groups were significant. The difference in gain between the full-fed pigs and the limited-fed pigs on the last half day before they were weighed off the experiment indicated that the limited-fed pigs carried more fill, which partially accounts for their lower dressing per cent. However, the limited-fed pigs were less fat and it has been shown by Scott (1930) and by others, that fatter hogs tend to yield a higher proportion of carcass to live weight. The indicated difference in "fill" between the full- and limited-fed pigs made it necessary to calculate yields of the various cuts as percentages of chilled carcass weight.

The differences in equivalent yield of loin as percentage of chilled carcass weight, both unadjusted and adjusted for quality (.68 and 1.80 per cent, respectively), were in favor of the limited-fed pigs. These differences were highly significant. The difference in equivalent yield of loin as percentage of filled live weight was in favor of the full-fed pigs before adjusting for quality (.71 per cent, highly significant) but after adjusting for quality there was no differ-

TABLE 4 -- SUMMARY OF CARCASS MERIT BY FEEDING LEVELS IN EACH LINE AND CROSS

Breeding	Feed Level	Sl. Wt. On Feed (lbs.)	Dressing %	Loin Equiv. % Ch. Car. Wt.		Loin Equiv. % Live Weight		Mean Wt'd Score‡
				Unadj.	Adj.	Unadj.	Adj.	
II	Full	204	70.5	65.37	69.87	46.06	49.19	3.78
	Ltd.	205	68.9	65.07	70.26	44.83	48.40	3.96
VI	Full	208	70.2	63.99	67.24	44.93	47.20	3.58
	Ltd.	206	69.2	64.56	66.99	44.64	46.30	3.46
V	Full	194	71.0	66.56	74.14	47.28	52.68	4.34
	Ltd.	204	70.8	64.94	70.92	45.95	50.16	4.09
II x VI	Full	204	71.4	64.60	66.90	46.15	47.82	3.42
	Ltd.	207	70.9	64.84	68.58	46.00	48.64	3.67
II x V	Full	206	73.4	64.71	70.67	47.46	51.83	4.08
	Ltd.	207	69.8	65.46	71.77	45.70	50.10	4.15
V x VI	Full	210	71.1	63.89	64.95	45.40	46.16	3.20
	Ltd.	209	69.5	64.75	69.11	45.03	48.06	3.80
II x D	Full	204	71.3	64.42	67.95	45.92	48.43	3.64
	Ltd.	208	68.2	65.59	70.55	44.73	48.14	3.91
VI x D	Full	208	71.6	62.73	64.40	44.67	45.90	3.28
	Ltd.	212	68.7	64.06	66.48	43.98	45.62	3.43
V x D	Full	204	71.6	64.65	69.62	46.32	49.87	3.92
	Ltd.	202	68.8	65.96	72.23	45.41	49.74	4.13
D x (II x VI)	Full	207	71.4	62.39	62.50	44.57	44.64	3.01
	Ltd.	210	69.9	64.10	66.89	44.77	46.69	3.46
Duroc	Full	204	72.0	61.68	58.15	44.39	41.86	2.30
	Ltd.	210	70.2	63.13	62.35	44.30	43.72	2.86
Means	Full	205	71.4	64.09	66.94	45.74	47.78	3.50
	Ltd.	207	69.5**	64.77**	68.74**	45.03**	47.78	3.72*
Std. Err. Mean Diff.			.3	.25	.62	.18	.44	.08

‡ Of ham, loin, shoulder and belly.
* $P \leq .05$
** $P \leq .01$

ence between feeding levels. The lower unadjusted equivalent yield of loin per unit of filled liveweight for limited-fed pigs can be accounted for by their lower dressing percentage. This disadvantage for carcasses from limited-fed pigs was counterbalanced by the significantly higher scores of their wholesale cuts, making carcasses from limited-fed and full-fed pigs equal in equivalent yield of loin per unit of live weight, adjusted for quality.

Conformation and Muscling (Table 5 and Appendix Table 25). There was little difference in body length between the full-fed and limited-fed groups. However, leg length was significantly (8 mm.) longer in the limited-fed pigs, presumably because they were slaughtered when about two weeks older than the full-fed pigs.

The percentage of lean in the chilled carcass, estimated by McMeekan's (1941) regression equation from the width and depth of cross-section of the longissimus dorsi muscle, was significantly (2.5 per cent) higher for limited-fed than for the full-fed pigs. The product of width and depth of loin muscle also

TABLE 5 -- SUMMARY OF ITEMS INDICATING CONFORMATION AND MUSCLING BY FEEDING LEVELS IN EACH LINE AND CROSS

Breeding	Feed Level	B.L. (mm.)	L.L. (mm.)	Est. % Lean of Ch. Car. Wt. (Mc-Meekan)	Loin WxD (Cm.^{2})	Ham WxD (Cm.^{2})	Lean Cuts: % Ham, Loin, Sh. of Ch. Car. Wt.	Lean Cuts: % Ham, Loin, Sh., L.T. of Ch. Car.	% Bone of Ch. Car. Wt.
II	Full	749	555	52.0	43.0	79.0	51.5	58.3	8.43
	Ltd.	741	546	50.1	37.9	78.3	51.1	58.4	8.46
VI	Full	721	543	48.4	36.8	79.7	48.8	56.6	8.11
	Ltd.	718	553	51.1	37.7	81.6	50.9	58.3	8.52
V	Full	698	559	53.6	43.4	84.0	53.0	60.9	8.94
	Ltd.	701	565	49.9	43.8	80.7	51.4	58.3	8.38
II x VI	Full	734	553	48.3	37.6	84.4	49.5	57.6	8.49
	Ltd.	734	564	49.5	38.1	79.5	51.4	58.7	8.31
II x V	Full	731	556	48.6	43.5	83.8	50.2	57.4	8.14
	Ltd.	723	558	52.7	44.9	79.3	51.3	59.0	7.98
V x VI	Full	710	536	42.1	32.4	73.9	48.5	52.5	7.82
	Ltd.	710	550	49.7	40.3	79.1	50.5	57.9	8.09
II x D	Full	723	560	49.2	39.3	77.7	50.2	57.2	8.44
	Ltd.	716	555	52.4	43.0	80.5	51.2	59.4	8.82
VI x D	Full	716	538	46.3	38.9	72.6	46.7	54.3	7.95
	Ltd.	711	546	47.3	40.7	74.2	49.2	56.7	8.16
V x D	Full	703	539	45.5	37.9	76.7	49.4	57.8	8.04
	Ltd.	690	552	51.5	42.8	79.8	52.4	60.6	8.56
D x (II x VI)	Full	727	535	43.3	33.7	76.0	47.2	53.6	8.03
	Ltd.	716	547	48.5	39.8	74.9	49.2	56.5	7.89
Duroc	Full	694	526	40.3	30.4	60.3	44.4	51.0	7.56
	Ltd.	712	550	41.8	32.5	65.9	47.8	54.8	7.69
Means	Full	719	545	47.0	37.9	77.1	49.0	56.1	8.18
	Ltd.	716	553*	49.5*	40.1*	77.6	50.6**	58.0**	8.26
Std. Err. Mean Diff.		2.8	2.9	.95	1.06	1.1	.40	.56	.09

* $P \leq .05$
** $P \leq .01$

was significantly (2.2 cm.^{2}) larger for the limited-fed pigs. However, the similar product of width and depth of ham muscle was nearly as large for the full-fed as for the limited-fed pigs, and the difference was not significant.

Actual yields of ham, loin and shoulder as a per cent of chilled carcass weight were 1.6 per cent higher and the yields of ham, loin, shoulder and lean trimming as a per cent of chilled carcass weight were 1.9 per cent higher for the limited-fed pigs. Both of these differences were highly significant.

The difference between feeding levels in per cent of "bone" in the carcass was small and non-significant.

Fatness (Table 6 and Appendix Table 26). All items indicative of fatness show that carcasses of the full-fed pigs contained significantly more fat than those of limited-fed pigs. The differences were 2.2 mm. in mean backfat thickness, 2.4 mm. in thickness of fat on ham and 1.5 mm. in thickness of belly.

TABLE 6 -- SUMMARY OF ITEMS INDICATING FATNESS BY FEEDING LEVELS IN EACH LINE AND CROSS

Breeding	Feed Level	Mean B.F. Th. (mm.)	Th. of Fat on Ham (mm.)	Belly Th. in Flank (mm.)	% F.B., F.T., L. F., and Belly of Ch. Car. Weight	% F.B., F.T., L.F. of Ch. Car. Wt.	Est. % Fat in Edible Portion of Carcass (Hankins)	Est. % Fat in Edible Portion of Carcass (Warner)	Est. % Fat of Ch. Car. Weight (McMeekan)
II	Full	34.8	25.8	22.3	33.2	21.4	46.8	50.5	40.3
	Ltd.	35.2	28.2	21.2	33.1	21.9	47.0	50.3	40.2
VI	Full	38.0	29.6	24.4	35.3	23.6	48.8	50.5	40.4
	Ltd.	34.2	25.7	23.5	33.2	22.3	46.4	48.2	38.8
V	Full	32.7	24.6	20.8	30.1	18.9	45.4	47.1	40.1
	Ltd.	33.9	24.3	21.3	33.3	22.3	46.2	50.0	40.4
II x VI	Full	36.9	25.8	23.7	33.8	22.1	48.1	49.2	40.9
	Ltd.	37.6	25.5	22.5	33.0	22.3	48.5	48.0	37.9
II x V	Full	36.5	28.6	24.2	34.5	22.8	47.8	49.3	40.9
	Ltd.	35.2	26.8	22.2	33.0	21.7	47.0	49.2	41.0
V x VI	Full	42.0	32.8	24.5	37.2	24.9	51.2	53.0	45.6
	Ltd.	38.4	30.1	21.9	34.0	22.4	49.0	50.5	44.3
II x D	Full	35.3	25.8	22.2	34.3	22.8	47.1	49.9	40.9
	Ltd.	33.8	25.1	22.4	31.7	20.3	46.2	47.5	40.3
VI x D	Full	43.6	34.6	22.8	37.8	25.6	52.2	52.9	48.2
	Ltd.	41.2	31.1	21.2	35.2	23.5	50.7	51.2	46.6
V x D	Full	37.6	31.4	23.9	34.1	22.4	48.5	51.0	43.5
	Ltd.	32.9	23.5	20.6	30.8	20.1	45.6	46.5	41.8
D x (II x VI)	Full	42.8	34.0	24.1	38.5	26.4	51.8	54.1	44.8
	Ltd.	39.7	30.1	22.4	35.6	23.8	49.8	52.4	43.6
Duroc	Full	48.6	41.9	27.0	41.4	28.6	55.4	57.2	52.6
	Ltd.	42.4	38.5	23.9	37.5	25.6	51.5	53.6	47.3
Means	Full	39.0	30.5	23.6	35.5	23.6	49.4	51.3	43.5
	Ltd.	36.8**	28.1*	22.1**	33.7**	22.4*	48.0**	49.8**	42.0*
Std. Err. Mean Diff.		.7	.92	.35	.53	.5	.44	.54	.49

* $P \leq .05$
** $P \leq .01$

Actual yield of fat cuts as a percentage of the chilled carcass was 1.2 per cent higher for the full-fed pigs when the belly was excluded and 1.8 per cent higher when the belly was included.

The estimated proportion of fat in the edible portion of the carcass or in the whole chilled carcass was about 1.5 per cent higher for full-fed than for limited-fed pigs, whether the estimate was based on mean thickness of backfat (Hankins and Ellis, 1934), on yield of backfat and trimmed belly (Warner, *et al.*, 1934), or on thickness of backfat at last rib (McMeekan, 1941). The estimated percentage of fat in the edible portion of the carcass was higher when the regression was based on yield of fatback and trimmed belly than when based on the mean backfat thickness, but the difference between feeding levels remained the same. All three estimates of fat emphasize the excessively fat nature of hog carcasses.

Discussion. Results obtained here from limited feeding, as it affects rate and economy of gains and carcass composition, are in general agreement with those reported by Ellis and Zeller (1934), by Winters, *et al.* (1949), and by McMeekan (1940).

These results clearly demonstrate that when limited-fed and full-fed pigs were slaughtered at the same live weight, carcasses from the limited-fed pigs showed slightly greater muscular development and contained less fat, thus yielding wholesale cuts of higher quality. The fact that the limited-fed pigs were two weeks older when they were slaughtered probably accounted for their greater muscular development; however, there was no difference between feeding levels in per cent of "bone" in the chilled carcass. Apparently, restricting feed consumption to 87 per cent of that for full-fed pigs did not seriously interfere with maximum muscular development. The data on carcass composition showed that the additional feed consumed by the full-fed pigs was utilized for deposition of fat. This would suggest that nutrients consumed in excess of maintenance requirements are used first to satisfy the demands of the pigs inherent growth stimulus for muscle and bone, and that additional food energy is stored as fat.

The data on carcass composition for all breeding groups shows that the lower yield of chilled carcass per unit of live weight from the limited-fed pigs is largely accounted for by the difference in yield of fat. This lower dressing percentage of the limited-fed pigs tended to cancel their superiority in carcass quality. Hence no general advantage could be credited to limited feeding in terms of net carcass value per pound of live weight. However, there was a rather large increase in net carcass value from limited-feeding in those groups (e.g., Durocs) that yielded the fatter carcasses with relatively poor muscular development. In these groups, limited feeding caused the larger reductions in yields of fat and the greater increases in quality scores, because more of the food energy under full-feeding was being stored as fat. The limited ration satisfied the requirements of the inherently fatter pigs for growth of muscle and bone tissue, but probably slowed growth of muscle and bone as well as deposition of fat in the inbred and line cross groups that tended to store less fat under full feeding.

Even though the maintenance requirements of the limited-fed pigs had to be met for a longer period to reach the same final weight, their more economical gains may be explained in terms of energy relationships by: (1) the lower fat content of their carcasses—less energy storage per pound of gain, and (2) the probable reduction in energy lost through Specific Dynamic Action at the reduced feed intake. The small and uncertain increase in the digestibility of the ration under limited-feeding may not disagree with the work on steers reported by Forbes, *et al*. (1928, 1930, 1937), Mitchell and Hamilton (1932), and by Brody and Procter (1933). The difference in digestibility was small, even between the widely varying feeding levels reported by Brody and Procter

(1933); hence it is quite possible that the differences in the digestibility of the ration between the two feeding levels used in this investigation would be small and difficult to detect. Brody (1945) has shown that the difference in energy lost through Specific Dynamic Action accounts for most of the increase in net energy per unit of feed intake at reduced levels of intake.

It is recognized that the apparent inadequacy of the ration and the resultant slow rates of gain (Table 3) may have caused limited feeding to affect rate and efficiency of gain and composition of carcasses differently than would be the case under more optimum nutrition.

The fact that limited feeding failed to increase net carcass value per pound of live weight, except in the inherently fatter breeding groups, indicates that any advantage from limiting feed consumption during the entire period from weaning to market in commercial swine production must depend largely on lower feed costs per pound of gain for limited-fed pigs. However, the slower rate of gain and the longer feeding period required to reach market weight under limited feeding introduces additional expense for labor and equipment and may mean a less favorable market due to seasonal trends. Methods of limiting feed consumption that involve use of less costly feed stuffs, as may be the case when good pastures are utilized, could have greater practical merit than limited feeding in dry lot. Also, the practice of restricting feed consumption only during the last portion of the growing period may be more advantageous than the limited feeding during the whole period which was required for the present experiment.

B. Comparison of Strains and Their Crosses

Each of the four strains and the seven crosses was represented by a full-fed and a limited-fed lot. The general differences among these breeding groups are considered first.

Digestibility of Ration (Table 2 and Appendix Tables 21, 22 and 23). An analysis of the data from the two digestion trials indicated no significant differences between breeding groups in digestibility of any component of the ration.

Rate and Economy of Gains (Table 7 and Appendix Table 24). The data clearly demonstrate that the crosslines, the topcrosses and the outbred Durocs gained faster and more economically than the inbred lines. The advantage for the non-inbred groups ranged from .2 to .3 pounds more daily gain and from 25 to 45 pounds less feed per hundred pounds of gain. Among the inbred lines, Line V Hampshires gained more slowly and less economically than Poland China Lines II and VI. Daily feed consumption per hundred pounds of live weight for the non-inbred groups ranged from 5 to 18 per cent above that of the inbreds as a group. The differences between the inbred and non-inbred groups, and those between the three inbred lines were highly significant for average daily gain, feed requirements, and age at final weight. The differences between the eight non-inbred groups were smaller and only those in gain and in feed requirements were significant. The superior rate of growth of the crosses was expressed during the suckling period, as indicated by their heavier initial (56-day) weights compared with the inbreds.

TABLE 7 -- AVERAGES OF GAINS, FEED CONSUMPTION AND UTILIZATION, BY LINES AND CROSSES

Breeding Group	Inbr. %	No. Pigs St'd	No. Pigs End	Init. Wt./ Pig	Fin. Wt./ Pig (pounds)	Gain /Day /Pig (pounds)	Feed Cons. /Cwt. /Day	Feed Req. /Cwt. Gain	Age Off Expt. (days)
Line II	43.18	16	14	29.8	204	1.00	3.85	358	218
Line VI	34.08	14	13	30.6	207	1.06	4.48	409	222
Line V	41.58	16	11	25.7	174	.63	3.77	452	257
Mean Inbreds	39.61	46	38	28.7	195	.90	4.03	406	232
II x VI	9.00	16	12	35.2	206	.93	4.04	416	215
II x V		16	16	36.2	207	1.19	4.11	351	200
V x VI		16	16	32.9	209	1.21	4.57	373	200
Mean Crosslines	3.00	48	44	34.8	207	1.11	4.24	380	205
II x D		16	16	30.9	207	1.13	4.32	368	212
VI x D		16	16	32.1	210	1.33	4.79	356	190
V x D		16	16	29.2	203	1.12	4.24	353	212
Mean Topcrosses		48	48	30.7	207	1.19	4.45	359	205
D x (II x VI)		16	16	31.9	209	1.23	4.75	382	200
Duroc		16	16	30.9	207	1.22	4.63	365	198
Mean All Non-Inbreds		128	124	32.4	207	1.17	4.43	370	203

It should be noted that the rates of gain in all breeding groups were unusually low. The fact that half of the pigs were limited to roughly 87 per cent of a full feed was partially responsible. However, even the gains of the full-fed pigs were much lower (by .2 to .4 pounds per pig per day) than they had been in previous experiments when the breeding groups were essentially the same. An inadequate ration presumably accounted for this poor growth performance. Pantothenic acid deficiency symptoms were manifested in the form of "goose stepping," scouring and decreased gains after the experiment had been in progress for about two months. Calcium pantothenate was added to the ration shortly after these conditions appeared and the symptoms were soon alleviated.

The II x VI full- and limited-fed lots and the II x Duroc full-fed lot were the only lots where the "goose stepping" appeared; however, all of the pigs showed some scouring and the gains were very low during this period. Rate of gain was extremely slow for pigs of the II x VI linecross, and of inbred Line V. The II x VI crossline group and the Line V inbred group were in a poor state of health throughout the trial. The fact that a number of pigs had to be removed from the experiment in some of the groups is evidence of the lack of thriftiness of the pigs in general.

Carcass Merit (Table 8 and Appendix Table 24). Rather large and significant differences existed between most of the breeding groups in items concerned with net carcass merit. Some of the extremes in live conformation and in desirability of carcass are shown in Figure 5. The Line V Hampshires were superior to all groups in net carcass merit and seemed to transmit characteristics necessary for superior carcasses in crosses with inbred Poland China Line II and when topcrossed on Durocs. However, the Hampshire Line V crossed with Poland China Line VI yielded only mediocre carcasses. The Line II inbred Poland China line tended to be intermediate in net carcass merit as a line and in crosses with Line VI and Durocs, but was superior in this respect in crosses with Line V. The Poland China Line VI was the poorest of the three inbred lines as a line and also in its crosses.

TABLE 8 -- SUMMARY OF CARCASS MERIT BY LINES AND CROSSES

Breeding	Sl. Wt. On Feed (lbs.)	Dress-ing %	Loin Equiv. % Ch. Car. Wt. Unadj.	Adj.	Loin Equiv. % Live Weight Unadj.	Adj.	Mean Wt'd Score*
II	204	69.7	65.22	70.06	45.44	48.80	3.87
VI	207	69.7	64.28	67.12	44.78	46.75	3.52
V	199	70.9	65.75	72.53	46.62	51.42	4.22
Mean Inbreds	203	70.1	65.08	69.90	45.61	48.99	3.87
II x VI	206	71.2	64.72	67.74	46.08	48.23	3.54
II x V	206	71.6	65.08	71.22	46.58	50.96	4.12
V x VI	210	70.3	64.32	67.03	45.22	47.11	3.50
Mean Crosslines	207	71.0	64.71	68.66	45.96	48.77	3.72
II x D	206	69.8	65.00	69.25	45.32	48.28	3.78
VI x D	210	70.2	63.40	65.44	44.32	45.76	3.36
V x D	203	70.2	65.30	70.92	45.86	49.80	4.02
Mean Topcrosses	206	70.1	64.57	68.54	45.17	47.95	3.72
D x (II x VI)	208	70.6	63.24	64.70	44.67	45.66	3.24
Duroc	207	71.1	62.40	60.25	44.34	42.79	2.58
Mean All Non-Inbreds	207	70.6	64.18	67.07	45.30	47.32	3.32

* Of ham, loin, shoulder and belly.

The purebred Durocs yielded the least desirable carcasses, in terms of yields and quality of the wholesale cuts. However, the topcrosses of the three

	154-Day Weight (lbs.)	Daily Gain (lbs.)	Carcass Yield as % Live Weight				
			Total	Ham	Loin	Sho.	Belly
Duroc Barrow No. 9	121	1.12	74.9	12.1	7.6	11.3	10.0
(IIxV) Poland-Hamp. Gilt No. 510	148	1.35	71.5	15.5	11.0	12.7	7.3

	Relative Desirability				% Equiv. Yield Loin	
	Ham	Loin	Shoulder	Belly	Unadj	Adjusted
Buroc Barrow No. 9	.83	.80	.80	.80	44.0	38.6
(IIxV) Poland-Hamp. Gilt No. 510	1.20	1.20	1.20	1.20	48.1	57.1

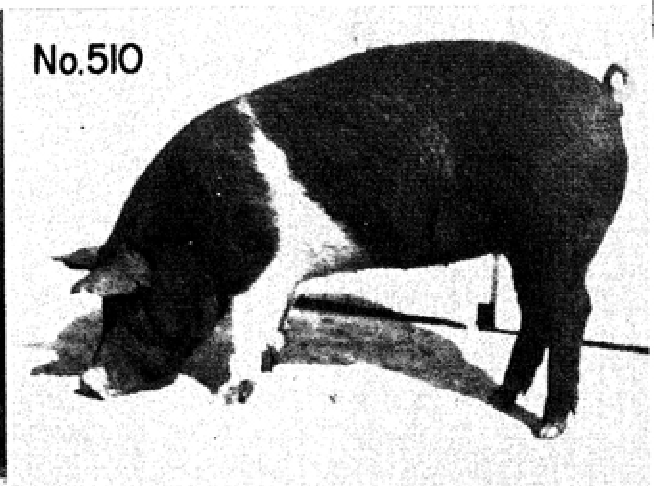


Figure 5.--Examples of extremes in live conformation and in desirability of carcass. In the section above are shown a Duroc full-fed barrow, No. 9, and two photographs of a Poland-Hampshire full-fed gilt, No. 510.

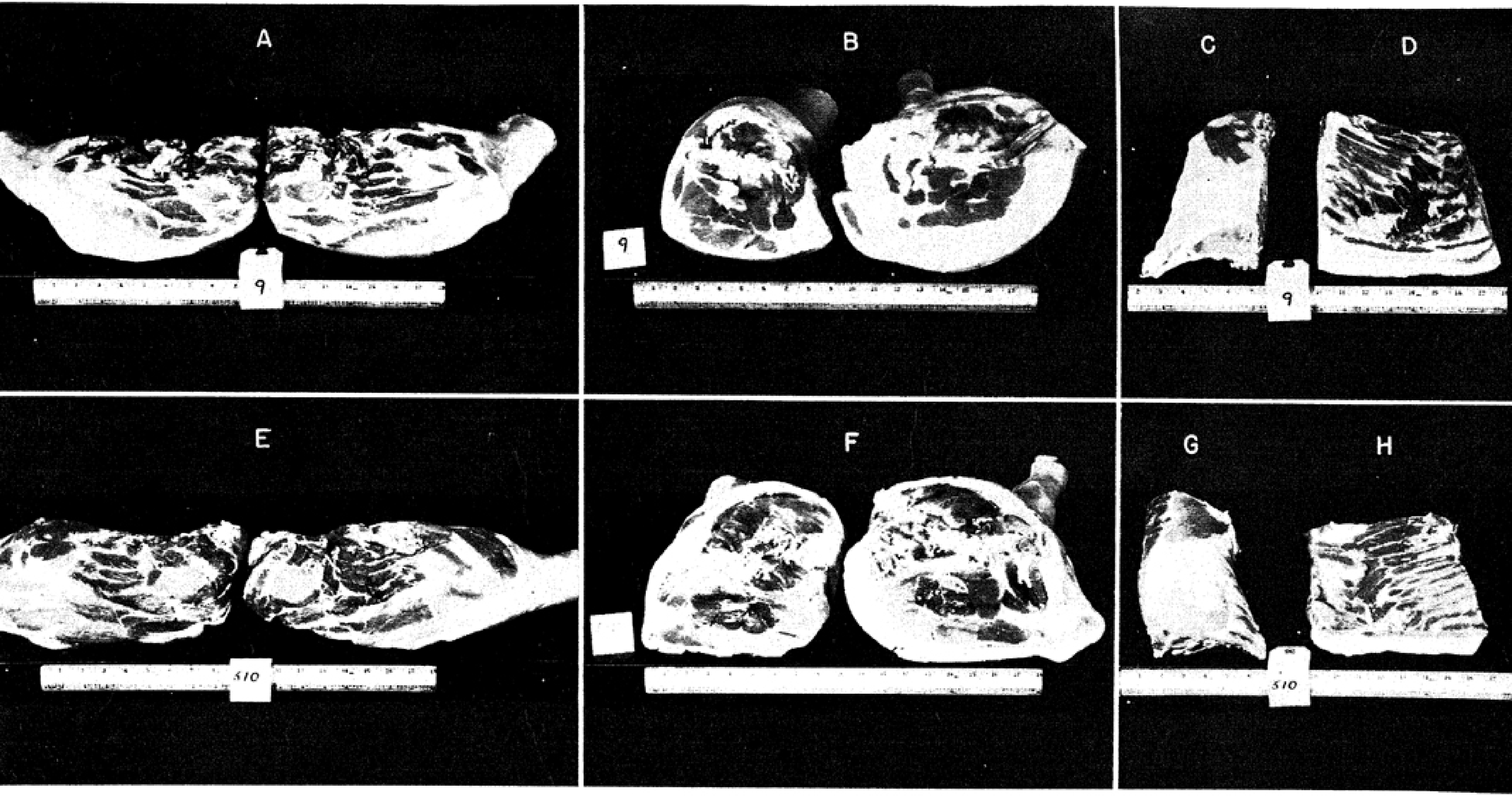


Figure 5 (Continued).--In the top row of photographs on this page are shown the trimmed cuts from the Duroc barrow as follows: Hams (A), shoulders (B), loin (C), and belly (D). In the lower row are shown the corresponding cuts from the Poland-Hampshire gilt (E, F, G, and H). Note width through the hams of the Poland-Hampshire gilt.

inbred lines on Durocs yielded carcasses nearly as desirable as those of the inbred lines themselves. The cross of Durocs on II and VI gilts produced pigs poorer in yield of loin equivalent than the average for topcrosses of Lines II and VI on Durocs, especially after adjustment was made for quality of cuts. Possibly a difference in the maternal environment (e.g., milk production) provided by the II x VI linecross dams and by the Duroc dams was responsible.

The linecross pigs dressed slightly higher than the inbreds, but there was little difference between the inbreds and crosslines in equivalent yield of loin per unit of live weight either unadjusted or adjusted for quality. Equivalent yield of loin per unit of chilled carcass weight was slightly higher for the inbreds, particularly after adjusting for the somewhat higher scores for quality of cuts from the inbreds.

TABLE 9 -- SUMMARY OF ITEMS INDICATING CONFORMATION AND MUSCLING BY LINES AND CROSSES

Breeding	B.L. (mm.)	L.L. (mm.)	Est. % Lean of Ch. Car. Wt. (Mc-Meekan)	Loin WxD (cm.^{2})	Ham WxD (cm.^{2})	Lean Cuts: % Ham, Loin, Sh. of Ch. Car. Wt.	Lean Cuts: % Ham, Loin, Sh., L.T. of Ch. Car.	% Bone of Ch. Car. Wt.
II	745	550	51.0	40.4	78.6	51.3	58.4	8.44
VI	720	548	49.8	37.2	80.6	49.8	57.4	8.32
V	700	562	51.8	43.6	82.4	52.2	59.6	8.66
Mean Inbreds	722	553	50.9	40.4	80.5	51.1	58.5	8.47
II x VI	734	558	48.9	37.8	82.0	50.4	58.2	8.40
II x V	727	557	50.6	44.2	81.6	50.8	58.2	8.06
V x VI	710	543	45.9	36.4	76.5	49.5	55.2	7.96
Mean Crossbreds	724	553	48.5	39.5	80.0	50.2	57.2	8.14
II x D	720	558	50.8	41.2	79.1	50.7	58.3	8.63
VI x D	714	542	46.8	39.8	73.4	48.0	55.5	8.06
V x D	696	546	48.5	40.4	78.2	50.9	59.2	8.30
Mean Topcrosses	710	549	48.7	40.5	76.9	49.9	57.7	8.33
D x (II x VI)	722	541	45.9	36.8	75.4	48.2	55.0	7.96
Duroc	703	538	41.0	31.4	63.1	46.1	52.9	7.62
Mean All Non-Inbreds	716	548	47.3	38.5	76.2	49.3	56.6	8.12

Conformation and Muscling (Table 9 and Appendix Table 25). Differences were large and highly significant in body length among the four parent strains (Lines II, VI, V and Duroc).

Linecrosses were slightly inferior to the parent inbred lines (particularly the V x VI cross) in all items indicative of muscular development and in per cent "bone" in the chilled carcass. In leg length, the three inbred lines were similar, but significantly longer than the Durocs. Crosses tended to be intermediate in length of both body and leg, compared with the parent strains. The older ages at which the inbred pigs were slaughtered presumably accounted for their greater muscular development. The Durocs as a group showed a marked and highly significant inferiority in all items indicative of muscular development. However, the topcrosses of Lines II, VI and V on Durocs closely approached the inbred lines in muscular development and were significantly superior to the Duroc carcasses.

Fatness (Table 10 and Appendix Table 26). Carcasses from the inbred pigs of the three lines were slightly less fat than those of their crosses. The non-inbred Durocs produced the fattest carcasses, although carcasses from the

TABLE 10 -- SUMMARY OF ITEMS INDICATING FATNESS BY LINES AND CROSSES

Breeding	Mean B.F. Th. (mm.)	Th. of Fat on Ham (mm.)	Belly Th. in Flank (mm.)	% F.B., F.T.,L.. F., and Belly of Ch. Car. Weight	% F.B., F.T., L.F. of Ch. Car. Wt.	Est. % Fat in Edible Portion of Carcass (Hankins)	Est. % Fat in Edible Portion of Carcass (Warner)	Est. % Fat of Ch. Car. Weight (McMeekan)
II	35.0	27.0	21.8	33.2	21.6	46.9	50.4	40.2
VI	36.1	27.6	24.0	34.2	23.0	47.6	49.4	39.6
V	33.3	24.4	21.0	31.7	20.6	45.8	48.6	40.2
Mean Inbreds	34.8	26.3	22.3	33.0	21.7	46.8	49.5	40.0
II x VI	37.2	25.6	23.1	33.4	22.2	48.3	48.6	39.4
II x V	35.8	27.7	23.2	33.8	22.2	47.4	49.2	41.0
V x VI	40.2	31.4	23.2	35.6	23.6	50.1	51.8	45.0
Mean Crosslines	37.7	28.2	23.2	34.3	22.7	48.6	49.9	41.8
II x D	34.6	25.4	22.3	33.0	21.6	46.6	48.7	40.6
VI x D	42.4	32.8	22.0	36.5	24.6	51.4	52.0	47.4
V x D	35.2	27.4	22.2	32.4	21.2	47.0	48.8	42.6
Mean Topcrosses	37.4	28.5	22.2	34.0	22.5	48.3	49.8	43.5
D x (II x VI)	41.2	32.0	23.2	37.0	25.1	50.8	53.2	44.2
Duroc	45.5	40.2	25.4	39.4	27.1	53.4	55.4	50.0
Mean All Non-Inbreds	39.0	30.3	23.1	35.1	23.4	49.4	51.0	43.8

Duroc x (II x VI) and the VI x Duroc crosses approached the Durocs in fatness. The II x Duroc and the V x Duroc were much less fat than the non-inbred Durocs and were actually only slightly fatter than the inbred lines. The differences between the inbreds and the non-inbreds and the differences between the eight non-inbred groups were large and highly significant for most items indicative of fatness. Differences in fatness between inbreds of the three lines were small and non-significant.

Discussion. The results on the digestibility of the ration disagree with those presented by Willham and Craft (1939) on the effect of inbreeding on digestibility, where they reported a significant difference between inbred and outbred Duroc pigs in the digestibility of nitrogen-free extract and protein.

The difference between the inbreds and crosslines in feed required per hundred pounds of gain was greater in this trial than it had been in previous experiments at this station with similar breeding groups. It was also greater than the differences reported by Dickerson, *et al.* (1946), and Sierk and Winters (1951) between inbred and linecross pigs. The linecross pigs consumed more feed per hundred pounds of live weight per day, made much more rapid gains and yielded carcasses with a higher fat content.

Topcrossing inbred boars on outbred Duroc sows did not result in more rapid and economical gains than for the outbred Durocs, but the topcrosses did yield carcasses that were markedly superior to those from the Durocs. The effect of heterosis will be considered in more detail under paired comparisons of crosses with parent lines.

In general, the highest levels of feed consumption tended to be associated with the most rapid gains and the fattest carcasses (e.g., the Durocs, Duroc x (II x VI), VI x Duroc and VI x V). The rapid, fat gains that were made by these groups indicates a rather high energetic efficiency. Possible explanations would be: (1) a larger proportion of feed consumed in excess of maintenance requirements available for fat deposition, (2) low energy losses through Specific Dynamic Action, even at high feed intakes, or (3) a low daily maintenance requirement per unit of live weight. Even though the Durocs have a large appetite they appear to have a low inherent growth impulse for muscle and bone tissue thus converting a large part of their feed energy into fat.

The general differences between breeding groups in rate, economy and composition of gains are believed to be due to fundamental differences in appetite, in dissipation of food energy as heat and in the physiological mechanisms operative in the conversion of nutrients into the different body tissues. Heterosis from crossing unrelated strains is simply a special type of inherent influence on the metabolic processes.

C. Comparison of Full-Fed Crosses with Means of Full-Fed Parent Strains

These comparisons provide estimates of heterosis effects on appetite as well as on utilization of feed consumed.

Digestibility of Ration (Table 2 and Appendix Tables 21, 22 and 23). There were no differences between the full-fed crosses and the mean of the full-fed parental groups in the digestibility of the ration.

Rate and Economy of Gains (Table 11 and Appendix Table 27). The full-fed crosslines excelled the average of the inbred parental lines by 6 pounds

TABLE 11 -- GAINS, FEED CONSUMPTION AND UTILIZATION COMPARING FULL-FED CROSSES WITH MEANS OF FULL-FED PARENTAL GROUPS

Breeding Group	Feed Level	Inbr. %	No. Pigs St'd	No. Pigs End	Init. Wt./ Pig	Fin. Wt./ Pig (pounds)	Gain /Day /Pig (pounds)	Feed Cons. /Cwt. /Day	Feed Req. /Cwt. Gain	Age Off Expt. (days)
II and VI	Full	37.74	15	13	30.0	205	1.01	4.31	402	215
II x VI	Full	9.00	8	6	35.1	205	.97	4.20	408	200
II and V	Full	42.02	16	11	27.4	198	.82	3.93	416	234
II x V	Full	0.0	8	8	36.1	207	1.26	4.33	358	192
V and VI	Full	36.58	15	12	28.1	201	.89	4.27	439	238
V x VI	Full	0.0	8	8	32.4	209	1.32	4.92	374	186
Inbreds	Full	38.78	23	18	28.5	201	.91	4.17	419	229
Crosslines	Full	3.0	24	22	34.5	207	1.18**	4.48	380	193**
Std. Err. Mean Diff.							.05			7.85
II and D	Full	21.59	16	14	29.9	204	1.11	4.58	387	200
II x D	Full	0.0	8	8	31.1	207	1.14	4.69	405	211
VI and D	Full	16.15	15	15	30.7	206	1.18	4.92	409	204
VI x D	Full	0.0	8	8	32.1	207	1.36	5.07	369	184
V and D	Full	20.42	16	13	28.1	200	1.00	4.54	424	222
V x D	Full	0.0	8	8	28.9	204	1.22	4.64	361	199
Parental Groups	Full	19.39	31	26	29.6	203	1.10	4.68	407	209
Topcrosses	Full	0.0	24	24	30.7	206	1.24**	4.80	378	198
Std. Err. Mean Diff.							.05			7.38
D and (II x VI)	Full	4.5	16	14	32.9	205	1.12	4.69	401	194
D x (II x VI)	Full	0.0	8	8	32.2	208	1.28	5.27	413	192
Mean All Parental Groups		25.57			29.6	203	1.02	4.46	411	215
Mean All Crosses		1.28			32.6	207	1.22	4.73	384	195

* $P \leq .05$
** $P \leq .01$

in weight at weaning, by approximately 7 per cent in feed consumption, by .27 pounds in daily gain, reached market weight 36 days earlier and required 39 pounds less feed per hundred pounds of gain. These differences were highly significant. The crossing advantage in post-weaning rate and economy of gain was significantly larger for the II x V and V x VI Poland China-Hampshire crosses than for the intra-breed cross of II x VI Poland China. In fact, the II x VI Poland China crossline group gave performance slightly inferior to the mean of the parental inbred lines. Similarly, Sierk and Winters (1951) reported little improvement in performance from crossing inbred lines within the Poland China breed, but greatly superior performance from crossing inbred lines between breeds. Such results emphasize the importance of genetic diversity in obtaining maximum heterosis from crosses.

The advantage of topcrosses over the mean of the parental groups was .14 pounds in average daily gain and twenty-nine pounds in feed required per hundred pounds of gain. These differences were highly significant, but smaller than those for the linecrosses. Topcrosses consumed only 2.5 per cent more feed per unit live weight daily and reached market weight 11 days earlier. Smaller differences would be expected, because the difference in degree of inbreeding between crosses and parent lines was only half as large for the topcrosses as for the linecrosses. The fact that the topcrosses were all suckled by the Duroc sows may explain the smaller (1-pound) advantage in weaning weight for topcrosses than for the linecrosses.

TABLE 12 -- SUMMARY OF CARCASS MERIT COMPARING FULL-FED CROSSES WITH MEANS OF FULL-FED PARENTAL GROUPS

Breeding	Sl. Wt. On Feed (lbs.)	Dressing %	Loin Equiv. % Ch. Car. Wt. Unadj.	Loin Equiv. % Ch. Car. Wt. Adj.	Loin Equiv. % Live Weight Unadj.	Loin Equiv. % Live Weight Adj.	Mean Wt'd Score‡
II and VI	206	70.4	64.68	68.56	45.50	48.20	3.68
II x VI	204	71.4	64.60	66.90	46.15	47.82	3.42
II and V	199	70.8	65.96	72.00	46.67	50.94	4.06
II x V	206	73.4	64.71	70.67	47.46	51.83	4.08
V and VI	201	70.6	65.28	70.69	46.10	49.94	3.96
V x VI	210	71.1	63.89	64.95	45.40	46.16	3.20
Inbreds	202	70.6	65.31	70.42	46.09	49.69	3.90
Crosslines	207	72.0*	64.40	67.51	46.34	48.60	3.57
Std. Err. Mean Diff.		.52	.50	1.58	.42	1.09	.20
II and D	204	71.2	63.52	64.05	45.22	45.52	3.04
II x D	204	71.3	64.42	67.95	45.92	48.43	3.64
VI and D	206	71.1	62.84	62.70	44.66	44.53	2.94
VI x D	208	71.6	62.73	64.40	44.67	49.90	3.28
V and D	199	71.5	64.12	66.14	45.84	47.27	3.32
V x D	204	71.6	64.65	69.62	46.32	49.87	3.92
Parental Groups	203	71.3	63.49	64.30	45.24	45.77	3.10
Topcrosses	205	71.5	63.93	67.32*	45.64	48.07*	3.61*
Std. Err. Mean Diff.		.49	.47	1.50	.4	1.03	.20
D and (II x VI)	204	71.7	63.14	62.52	45.27	44.84	2.86
D x (II x VI)	207	71.4	62.39	62.50	44.57	44.64	3.01
Mean All Parental Groups	203	71.0	64.22	66.66	45.61	47.32	3.41
Mean All Crosses	206	71.7	63.91	66.71	45.78	47.81	3.51

‡ Of ham, loin, shoulder and belly.

* $P \leq .05$
** $P \leq .01$

The D x (II x VI) cross was superior to the mean of the two parent groups in daily gain but not in economy of gain. In general, the advantage of crosses over the parental mean was proportional to the increase in heterozygosity from crossing, as indicated by the inbreeding of the parent lines and by relationship between the lines crossed. Under full feeding, at least a part of the increased rate of gain for crosses was due to an increased rate of feed consumption.

Carcass Merit (Table 12 and Appendix Table 27). Linecrosses averaged significantly (1.4 per cent) higher than the inbred parent lines in dressing percentage, but yielded wholesale cuts of lower quality as shown by consumer desirability scores. Equivalent yield of loin per unit of live weight was little better for linecrosses than for the inbreds before adjusting for quality, because their higher dressing percentage represented an increase in the less valuable fat cuts. After adjusting for quality, equivalent yield of loin per unit of live weight was lower for linecrosses, but not significantly so. Equivalent yield of loin per unit of chilled carcass weight was still lower for linecrosses compared with parental inbreds, particularly when adjusted for quality of cuts, and these differences approached statistical significance.

The difference between the topcrosses and the parental groups were small and non-significant for dressing per cent and per cent yield of unadjusted loin equivalent either on a live weight or chilled carcass weight basis. However, the full-fed topcrosses were significantly superior to the mean of the full-fed parental groups in equivalent yield of loin adjusted for quality, on both a live weight and chilled carcass weight basis (differences of 2.3 and 3.0 per cent, respectively). The marked superiority of carcasses from topcrosses was due almost entirely to their significantly higher scores for quality of wholesale cuts (advantage of .51). As shown in Table 8, the topcross pigs tended to approach the superior inbred parent lines in net carcass value. These results are similar to those reported by Hutton and Russell (1939) from crossing Yorkshires with Chester Whites.

Conformation and Muscling (Table 13 and Appendix Table 28). The estimated content of lean in the chilled carcass (McMeekan, 1941) was higher for inbreds than for linecrosses by 5 per cent and this difference was highly significant. The inbreds were also significantly higher in per cent ham, loin and shoulder (1.7 per cent), and in percentage of bone (.34 per cent) in the chilled carcass. Mean area of cross-section of loin muscle was larger for inbreds than for linecrosses, but there was no difference in average size of ham muscle. These differences lacked significance and varied widely between crosses. The V x VI cross was particularly poor in muscle dimensions. Body and leg length were nearly alike for inbreds and crosses. The greater lean content for the inbreds than for the linecrosses at the same final live weight may have been partially due to the poor state of health of the Line V inbreds, which probably delayed fat deposition more than growth of muscle and bone.

Topcrosses showed greater muscular development than the parental average, but the difference was not quite large enough for significance at the .05 level. The topcrosses were very similar to the linecrosses in muscular development, although the Duroc parent was markedly deficient in this respect.

Fatness (Table 14 and Appendix Table 29). The full-fed crosslines tended to be definitely fatter than the full-fed inbreds. The differences that were significant at the .05 level were 3.3 mm. thicker backfat, 2.3 per cent higher percentage of fat cuts including belly, 2.0 per cent higher percentage of fat cuts excluding belly and 2.0 per cent higher estimated content of fat in the edible portion of the carcass based on mean thickness of backfat (Hankins and Ellis,

TABLE 13 -- SUMMARY OF ITEMS INDICATING CONFORMATION AND MUSCLING COMPARING FULL-FED CROSSES WITH MEANS OF FULL-FED PARENTAL GROUPS

Breeding	B.L. (mm.)	L.L. (mm.)	Est. % Lean of Ch. Car. Wt. (Mc-Meekan)	Loin WxD (cm^2.)	Ham WxD (cm^2.)	Lean Cuts % Ham, Loin, Sh. of Ch. Car. Wt.	Lean Cuts % Ham, Loin, Sh., L.T. of Ch. Car.	% Bone of Ch. Car. Wt.
II and VI	735	549	50.2	39.9	79.4	50.2	57.4	8.27
II x VI	734	553	48.3	37.6	84.4	49.5	57.6	8.49
II and V	724	557	52.8	43.2	81.5	52.2	59.6	8.68
II x V	731	556	48.6	43.5	83.8	50.2	57.4	8.14
V and VI	710	551	51.0	40.1	81.8	50.9	58.8	8.52
V x VI	710	536	42.1	32.4	73.9	48.5	52.5	7.82
Inbreds	723	552	51.3	41.1	80.9	51.1	58.6	8.49
Crosslines	725	548	46.3**	37.8	80.7	49.4*	55.8	8.15*
Std. Err. Mean Diff.	5.43	4.55	1.57	2.03	3.56	.81	2.12	.17
II and D	722	540	46.2	36.7	69.6	48.0	54.6	8.00
II x D	723	560	49.2	39.3	77.7	50.2	57.2	8.44
VI and D	708	534	44.4	33.6	70.0	46.6	53.8	7.84
VI x D	716	538	46.3	38.9	72.6	46.7	54.3	7.95
V and D	696	542	47.0	36.9	72.2	48.7	56.0	8.25
V x D	703	539	45.5	37.9	76.7	49.4	57.8	8.04
Parental Groups	709	539	45.9	35.7	70.6	47.8	54.8	8.03
Topcrosses	714	546	47.0	38.7	75.7	48.8	56.4	8.14
Std. Err. Mean Diff.	5.10	4.27	1.48	1.91	3.35	.76	1.99	.14
D and (II x VI)	714	540	44.3	34.0	72.4	47.0	54.3	8.02
D x (II x VI)	727	535	43.3	33.7	76.0	47.2	53.6	8.03
Mean All Parental Groups	716	545	47.98	37.8	75.3	49.1	56.4	8.22
Mean All Crosses	720	545	46.18	37.6	77.9	48.8	55.8	8.13

* $P \leq .05$
** $P \leq .01$

1934). The differences were in the same direction, but not significant for percentage of fat in the edible portion of the carcass when the estimates were based on yield of backfat and belly (Warner, *et al.*, 1934) and for percentage of fat in the chilled carcass estimated from backfat thickness at last rib (McMeekan, 1941).

In contrast with linecrosses, the topcrosses on Durocs yielded carcasses that averaged considerably less fat than the mean of the parental groups. The significant differences were 3.1 mm. thinner backfat, 3.7 mm. thinner fat on ham and 1.9 per cent less fat in the edible portion of the carcass estimated from mean backfat thickness (Hankins and Ellis, 1934). Differences in the other items indicating fatness were in the same direction; however, none of them was significant.

Discussion. The advantage in feed required per hundred pounds of gain for the full-fed crosses compared with the full-fed parental groups was much

TABLE 14 -- SUMMARY OF ITEMS INDICATING FATNESS COMPARING FULL-FED CROSSES WITH MEANS OF FULL-FED PARENTAL GROUPS

Breeding	Mean B.F. Th. (mm.)	Th. of Fat on Ham (mm.)	Belly Th. in Flank (mm.)	% F.B., F.T.,L. F., and Belly of Ch. Car. Weight	% F.B., F.T., L.F. of Ch. Car. Wt.	Est. % Fat in Edible Portion of Carcass (Hankins)	Est. % Fat in Edible Portion of Carcass (Warner)	Est. % Fat of Ch. Car. Weight (McMeekan)
II and VI	36.4	27.7	23.4	34.2	22.5	47.8	50.5	40.4
II x VI	36.9	25.8	23.7	33.8	22.1	48.1	49.2	40.9
II and V	33.8	25.2	21.6	31.6	20.2	46.1	48.8	40.2
II x V	36.5	28.6	24.2	34.5	22.8	47.8	49.3	40.9
V and VI	35.4	27.1	22.6	32.7	21.2	47.1	48.8	40.2
V x VI	42.0	32.8	24.5	37.2	24.9	51.2	53.0	45.6
Inbreds	35.2	26.7	22.5	32.9	21.3	47.0	49.4	40.3
Crosslines	38.5*	29.1	24.1	35.2*	23.3*	49.0*	50.5	42.5
Std. Err. Mean Diff.	1.46	1.91	1.11	.97	.85	.91	1.07	1.71
II and D	41.7	33.8	24.6	37.3	25.0	51.1	53.8	46.4
II x D	35.3	25.8	22.2	34.3	22.8	47.1	49.9	40.9
VI and D	43.3	35.8	25.7	38.4	26.1	52.1	53.8	46.5
VI x D	43.6	34.6	22.8	37.8	25.6	52.2	52.9	48.2
V and D	40.6	33.2	23.9	35.8	23.8	50.4	52.2	46.4
V x D	37.6	31.4	23.9	34.1	22.4	48.5	51.0	43.5
Parental Groups	41.9	34.3	24.7	37.2	25.0	51.2	53.3	46.4
Topcrosses	38.8*	30.6*	23.0	35.4	23.6	49.3*	51.3	44.2
Std. Err. Mean Diff.	1.37	1.80	1.04	.91	.79	.85	1.0	1.61
D and (II x VI)	42.8	33.8	25.4	37.6	25.4	51.8	53.2	46.8
D x (II x VI)	42.8	34.0	24.1	38.5	26.4	51.8	54.1	44.8
Mean All Parental Groups	39.1	30.9	23.9	35.4	23.4	49.5	51.6	43.8
Mean All Crosses	39.2	30.4	23.6	35.7	23.8	49.5	51.3	43.5

*P ≤ .05
**P ≤ .01

larger in the present trial than in previous trials at this station and much larger than in trials reported by Dickerson, *et al.* (1946), and by Sierk and Winters (1951). The disadvantage of parental inbreds may have been magnified by the apparent deficiency of the ration in certain essential vitamins. Also, the crosses reported by Dickerson, *et al.* (1946) were linecrosses within the Poland China breed. Winters, *et al.* (1935) and Lush, *et al.* (1939) reported an advantage for crossbreds over purebreds in economy of gain.

The fact that the inbred lines consumed less feed and stored less fat than their crosses indicates that they had relatively smaller amounts of energy left for storage as fat after satisfying their requirements for maintenance and for growth of muscle and bone tissue. The larger percentage of fat for the full-fed crosslines indicates that crossing of inbred lines stimulated appetite proportionately more than growth of muscle and bone. Thus the higher feed consumption of linecrosses increased fat deposition more than growth of muscle and bone, so that they averaged 36 days younger and showed less muscular development at slaughter weight, compared with parental inbreds.

Dickerson, *et al.* (1946) reported a non-significant difference between inbred lines and their crosses in fatness of carcass; however, the evidence suggested that the inbreds were slightly fatter. This disagreement in results would tend to indicate that the poor state of health of some of the inbred groups in the present investigation may have been a contributing factor to the low fat content of their carcasses.

Pigs of the Duroc parent line possessed a very large appetite relative to their rate of muscle and bone growth. Hence their carcasses contained a very high proportion of fat. The appetite of the topcrosses was only about 2.5 per cent above the mean for the Duroc and the inbred parent lines, but their rate of growth of muscle and bone was as rapid as for the crosslines and more rapid than for the inbreds. Thus topcrosses had somewhat less food energy available for storage as fat than the mean of the parent stocks. The topcrosses equaled or excelled the Durocs in rate and economy of gains and approached the inbred lines in net carcass value.

These results indicate that heterosis manifests itself through accelerated true growth (i.e., muscle and bone), increased appetite and more efficient utilization of food energy. The crosses seem to possess a metabolic system that is capable of ingesting and utilizing larger quantities of feed with proportionately less energy loss in the urine and through Specific Dynamic Action. However, no differences were detected in loss of fecal energy. Any reduction in urinary loss could represent increased storage in body tissues or a decline in energy metabolized for activity and for maintenance of body tissues.

Sierk and Winters (1951) concluded that the manifestations of heterosis in swine indicated an increased efficiency of metabolism. They further concluded that part of the apparently superior developmental system could be due to greater tolerance of varying environmental conditions.

D. Comparison of Crosses with Means of Parent Strains at Equal Rates of Feed Consumption

The present experiment was designed particularly to study the nature of heterosis when rate of feed consumption was equalized between crosses and parent lines. Feed consumption per unit of live weight for each cross was limited to that of the full-fed inbred lines which represented both parents of each linecross, but only one of the parents of each topcross.

Digestibility of Ration (Table 2 and Appendix Tables 21, 22 and 23). There were no differences between the limited-fed crosses and the mean of the full-fed parental groups in the digestibility of the dry matter of the ration.

Rate and Economy of Gains (Table 15 and Appendix Table 27). The limited-fed II x VI Poland China crossline group would not consume as much feed as the average for full-fed pigs of the two parental lines. This largely

TABLE 15 -- GAINS, FEED CONSUMPTION AND UTILIZATION COMPARISONS MADE ON AN EQUALIZED FEED INTAKE BASIS

Breeding Group	Feed Level	Inbr. %	No. Pigs St'd	No. Pigs End	Init. Wt./ Pig	Fin. Wt./ Pig (pounds)	Gain /Day /Pig	Feed Cons. /Cwt. /Day	Feed Req. /Cwt. Gain	Age Off Expt. (days)
II and VI	Full	37.74	15	13	29.98	205	1.01	4.31	402	215
II x VI	Ltd.	9.00	8	6	35.25	207	.88	3.87	424	230
II and V	Full	42.02	16	11	27.38	198	.82	3.93	416	234
II x V	Ltd.		8	8	36.25	207	1.12	3.89	343	208
V and VI	Full	36.58	15	12	28.10	201	.89	4.27	439	238
V x VI	Ltd.		8	8	33.38	209	1.09	4.21	372	213
Inbreds	Full	38.78	23	18	28.5	201	.91	4.17	419	229
Crosslines	Ltd.	3.00	24	22	35.0	208	1.03*	3.99	380	217
Std. Err. Mean Diff.							.05			7.85
II	Full	43.18	8	6	29.25	202	.94	3.98	380	211
II x D	Ltd.		8	8	30.75	208	1.13	3.96	330	213
VI	Full	32.30	7	7	30.71	208	1.08	4.65	424	219
VI x D	Ltd.		8	8	32.12	212	1.29	4.51	344	195
V	Full	40.85	8	5	25.5	194	.70	3.89	453	257
V x D	Ltd.		8	8	29.62	202	1.02	3.84	344	224
Inbreds	Full	38.78	23	18	28.5	201	.91	4.17	419	229
Topcrosses	Ltd.		24	24	30.8	207	1.15**	4.10	339**	211*
Parental Mean (Full-Inbr.) for Topcrosses (Ltd.-Dur.)		19.39	31	26	29.8	206	1.04*	4.12	378*	218
Std. Err. Mean Diff.							.05			7.38
II, V, VI	Full	38.78	23	18	28.49	201	.91	4.17	419	229
Duroc	Ltd.		8	8	31.12	210	1.18	4.07	336	208

* $P \leq .05$
** $P \leq .01$

accounts for the lowered feed intake per unit of live weight of the limited-fed crosslines compared to the mean of the full-fed inbreds.

Although the limited-fed crosslines consumed about 4 per cent less feed per unit weight daily, they gained .12 pounds more per pig daily than the full-fed parental inbreds. This difference was significant. The limited-fed line-crosses required 39 pounds less feed per hundred pounds of gain than the full-fed parental inbreds and required twelve fewer days to reach market weight. The limited-fed II x VI Poland China linecross was poorer than the full-fed parental inbreds in rate and economy of gain and results with this cross differed significantly from those for the two crossbred combinations.

Each limited-fed topcross was compared at the same daily feed allowance per unit live weight with the full-fed lot of the one inbred parent line. This comparison would include not only heterosis effects, but also half of any difference in the transmitted influence between the Durocs and the other parent line. The results show a marked and highly significant superiority of top-crosses over the inbreds in rate and economy of gain at the same level of feed intake. The limited-fed topcrosses gained .24 pound more per day, required 80 pounds less feed per hundred pounds of gain and reached market weight eighteen days earlier than the full-fed inbreds.

A better measure of heterosis alone can be obtained by comparing limited-fed topcrosses with the mean for the full-fed inbred and limited-fed Duroc parental groups, both of which were fed at the same rate as the topcrosses. In this comparison, topcrosses exceeded the parental mean by .11 pounds in daily gain, required 39 pounds less feed per hundred pounds of gain and reached market weight seven days earlier. These estimates for heterosis effects from topcrosses at equal rates of feed consumption were significant and of approximately the same size as those from the linecrosses.

TABLE 16 -- SUMMARY OF CARCASS MERIT COMPARISONS MADE ON AN EQUALIZED FEED INTAKE BASIS

Breeding	Feed Level	Sl. Wt. On Feed (lbs.)	Dressing %	Loin Equiv. % Ch. Car. Wt. Unadj.	Loin Equiv. % Ch. Car. Wt. Adj.	Loin Equiv. % Live Wt. Unadj.	Loin Equiv. % Live Wt. Adj.	Mean Wt'd Score‡
II and VI	Full	206	70.4	64.68	68.56	45.50	48.20	3.68
II x VI	Ltd.	207	70.9	64.84	68.58	46.00	48.64	3.67
II and V	Full	199	70.8	65.96	72.00	46.67	50.94	4.06
II x V	Ltd.	207	69.8	65.46	71.77	45.70	50.10	4.15
V and VI	Full	201	70.6	65.28	70.69	46.10	49.94	3.96
V x VI	Ltd.	209	69.5	64.75	69.11	45.03	48.06	3.80
Inbreds	Full	202	70.6	65.31	70.42	46.09	49.69	3.90
Crosslines	Ltd.	208	70.1	65.02	69.82	45.58	48.93	3.87
Std. Err. Mean Diff.			.52	.50	1.58	.42	1.09	.20
II	Full	204	70.5	65.37	69.87	46.06	49.19	3.78
II x D	Ltd.	208	68.2	65.59	70.55	44.73	48.14	3.91
VI	Full	208	70.2	63.99	67.24	44.93	47.20	3.58
VI x D	Ltd.	212	68.7	64.06	66.48	43.98	45.62	3.43
V	Full	194	71.0	66.56	74.14	47.28	52.68	4.34
V x D	Ltd.	202	68.8	65.96	72.23	45.41	49.74	4.13
Inbreds	Full	202	70.6	65.31	70.42	46.09	49.69	3.90
Topcrosses	Ltd.	207	68.6**	65.20	69.75	44.71**	47.83	3.82
Parental Mean (Full-Inbr.) for Topcrosses(Ltd.-Dur.)		206	70.4**	64.22*	66.38*	45.20	46.70	3.38*
Std. Err. Mean Diff.			.49	.47	1.50	.4	1.03	.20
II, V, VI	Full	202	70.6	65.31	70.42	46.09	49.69	3.90
Duroc	Ltd.	210	70.2	63.13	62.35	44.30	43.72	2.86

‡ Of ham, loin, shoulder and belly.

* P ≦ .05
** P ≦ .01

Carcass Merit (Table 16 and Appendix Table 27). The slight apparent superiority of the full-fed inbreds over the limited-fed crosslines in all carcass merit items could easily have been due to sampling errors.

The limited-fed topcrosses showed a highly significant reduction from the full-fed inbreds representing one parent of the topcross in dressing per cent (difference of 2 per cent). This difference was entirely responsible for the lower yield in loin equivalent as a per cent of live weight, both unadjusted and adjusted for quality (1.4 and 1.9 per cent, respectively) for the topcrosses.

Differences between the limited-fed topcrosses and the full-fed inbreds were negligible in other carcass merit items.

The limited-fed topcrosses dressed 1.8 per cent less than the mean of the parental full-fed inbreds and the limited-fed Durocs, and this difference was significant. This difference was responsible for the slightly but not significantly lower yield of unadjusted loin equivalent per unit of live weight. However, cuts from the limited-fed topcrosses scored significantly higher (.44) in quality than the parental mean and about the same as the inbreds. Hence, after adjusting for quality, the topcrosses had an advantage of 1.1 per cent in yield of loin equivalent on a live weight basis. In equivalent yields of loin per unit of chilled carcass weight the topcrosses had an advantage of 1.0 per cent before adjusting for quality and of 3.4 per cent after adjusting for quality. Both of these differences were significant.

TABLE 17 -- SUMMARY OF ITEMS INDICATING CONFORMATION AND MUSCLING - COMPARISONS MADE ON EQUALIZED FEED INTAKE BASIS

Breeding	Feed Level	B.L. (mm.)	L.L. (mm.)	Est. % Lean of Ch. Car. Wt. (Mc-Meekan)	Loin WxD (cm^2.)	Ham WxD (cm^2.)	Lean Cuts: % Ham, Loin, Sh. of Ch. Car. Wt.	Lean Cuts: % Ham, Loin, Sh., L.T. of Ch. Car.	% Bone of Ch. Car. Wt.
II and VI	Full	735	549	50.2	39.9	79.4	50.2	57.4	8.27
II x VI	Ltd.	734	564	49.5	38.1	79.5	51.4	58.7	8.31
II and V	Full	724	557	52.8	43.2	81.5	52.2	59.6	8.68
II x V	Ltd.	723	558	52.7	44.9	79.3	51.3	59.0	7.98
V and VI	Full	710	551	51.0	40.1	81.8	50.9	58.8	8.52
V x VI	Ltd.	710	550	49.7	40.3	79.1	50.5	57.9	8.09
Inbreds	Full	723	552	51.3	41.1	80.9	51.1	58.6	8.49
Crosslines	Ltd.	722	557	50.6	41.1	79.3	51.1	58.5	8.13*
Std. Err. Mean Diff.		5.43	4.55	1.57	2.03	3.56	.81	2.12	.17
II	Full	749	555	52.0	43.0	79.0	51.5	58.3	8.43
II x D	Ltd.	716	555	52.4	43.0	80.5	51.2	59.4	8.82
VI	Full	721	543	48.4	36.8	79.7	48.8	56.6	8.11
VI x D	Ltd.	711	546	47.3	40.7	74.2	49.2	56.7	8.16
V	Full	698	559	53.6	43.4	84.0	53.0	60.9	8.94
V x D	Ltd.	690	552	51.5	42.8	79.8	52.4	60.6	8.56
Inbreds	Full	723	552	51.3	41.1	80.9	51.1	58.6	8.49
Topcrosses	Ltd.	706**	551	50.4	42.2	78.2	50.9	58.9	8.51
Parental Mean for Topcrosses	(Full-Inbr.) (Ltd.-Dur.)	718*	551	46.6*	36.8**	73.4	49.4	56.7	8.09*
Std. Err. Mean Diff.		5.10	4.27	1.48	1.91	3.35	.76	1.99	.14
II, V, VI	Full	723	552	51.3	41.1	80.9	51.1	58.6	8.49
Duroc	Ltd.	712	550	41.8	32.5	65.9	47.8	54.8	7.69

* $P \leq .05$
** $P \leq .01$

Conformation and Muscling (Table 17 and Appendix Table 28). Differences between the full-fed inbreds and the limited-fed linecrosses were smaller than expected from experimental error for all items concerned with conformation and muscling except yield of "bone," which was significantly but only slightly lower for the linecrosses.

The limited-fed topcrosses averaged 17 mm. shorter in body length than the full-fed inbreds representing one parent of each of the topcrosses. This was a rather large and highly significant difference. Differences in other items indicative of conformation and muscling between these groups were small and not consistent or significant. The limited-fed pigs of the Duroc parent stock were shorter in body but not in leg, and showed much less muscular development than the inbred Poland China and Hampshire parent lines.

The limited-fed topcrosses were significantly (12 mm.) shorter in body than the parental mean of the full-fed inbred lines and the limited-fed Durocs; however, there was no difference in length of leg. In items indicative of muscular development the topcrosses showed a marked superiority. The significant differences were 3.8 per cent in estimated lean content of the chilled carcass (McMeekan, 1941) and 5.4 $cm.^2$ in estimated area of cross-section of loin muscle. Although not significant, the topcrosses also averaged higher by 4.8 $cm.^2$ in mean area of cross-section of ham muscle, 1.5 per cent in yield of lean cuts with the lean trim excluded and 2.2 per cent with lean trim included. The topcrosses also yielded significantly (.42 per cent) more "bone."

Fatness (Table 18 and Appendix Table 29). The limited-fed crosslines were only slightly fatter than the full-fed inbreds of the parent lines and none of the differences in items indicative of fatness were large enough to give assurance of their reality. The differences in fatness also were negligible between the full-fed inbreds of Lines II, V and VI and their topcrosses (on Durocs) that were fed at the same rate, and none of them were significant.

Both of the limited-fed Durocs and the limited-fed topcrosses were restricted to the same rate of feed consumption per pound of live weight as the three full-fed inbred lines (Table 15). The limited-fed topcrosses were definitely less fat than the mean of the parental full-fed inbreds and the limited-fed Durocs, even though the rates of feed consumption was equal. The significant differences were 2.8 mm. in mean backfat thickness, 6 mm. in thickness of fat on ham, 2.6 per cent in yield of fat cuts, including belly, 2.1 per cent in yield of fat cuts when belly was excluded, 1.7 per cent in fat in the edible carcass estimated from the mean backfat thickness (Hankins and Ellis, 1934) and 3.1 per cent when fat was estimated from yield of backfat and belly (Warner, *et al.*, 1934). Other indicators of fatness were lower for the topcrosses, but not significantly so.

Discussion. The fact that heterosis manifested itself in increased muscular growth even though feed intakes were equalized indicates that the crosses possessed a greater inherent growth impulse and that a more efficient metabolic system permitted the expression of this impulse. The increased muscular development and decreased fatness of topcrosses compared to the parental means at the same level of feed intake would indicate a rather marked increase in

TABLE 18 -- SUMMARY OF ITEMS INDICATING FATNESS - COMPARISONS MADE ON AN EQUALIZED FEED INTAKE BASIS

Breeding	Feed Level	Mean B.F. Th. (mm.)	Th. of Fat on Ham (mm.)	Belly Th. in Flank (mm.)	% F.B., F.T.,L. F., and Belly of Ch.Car. Weight	% F.B., F.T., L.F. of Ch. Car. Wt.	Est. % Fat in Edible Portion of Carcass (Hankins)	Est. % Fat in Edible Portion of Carcass (Warner)	Est. % Fat of Ch. Car. Weight (McMeekan)
II and VI	Full	36.4	27.7	23.4	34.2	22.5	47.8	50.5	40.4
II x VI	Ltd.	37.6	25.5	22.5	33.0	22.3	48.5	48.0	37.9
II and V	Full	33.8	25.2	21.6	31.6	20.2	46.1	48.8	40.2
II x V	Ltd.	35.2	26.8	22.2	33.0	21.7	47.0	49.2	41.0
V and VI	Full	35.4	27.1	22.6	32.7	21.2	47.1	48.8	40.2
V x VI	Ltd.	38.4	30.1	21.9	34.0	22.4	49.0	50.5	44.3
Inbreds	Full	35.2	26.7	22.5	32.9	21.3	47.0	49.4	40.3
Crosslines	Ltd.	37.1	27.5	22.2	33.3	22.1	48.2	49.2	41.1
Std. Err. Mean Diff.		1.46	1.91	1.11	.97	.85	.91	1.07	1.71
II	Full	34.8	25.8	22.3	33.2	21.4	46.8	50.5	40.3
II x D	Ltd.	33.8	25.1	22.4	31.7	20.3	46.2	47.5	40.3
VI	Full	38.0	29.6	24.4	35.3	23.6	48.8	50.5	40.4
VI x D	Ltd.	41.2	31.1	21.2	35.2	23.5	50.7	51.2	46.6
V	Full	32.7	24.6	20.8	30.1	18.9	45.4	47.1	40.1
V x D	Ltd.	32.9	23.5	20.6	30.8	20.1	45.6	46.5	41.8
Inbreds	Full	35.2	26.7	22.5	32.9	21.3	47.0	49.4	40.3
Topcrosses	Ltd.	36.0	26.6	21.4	32.6	21.3	47.5	48.4	42.9
Parental Mean (Full-Inbr.) for Topcrosses (Ltd.-Dur.)		38.8*	32.6*	23.2	35.2**	23.4*	49.2*	51.5**	43.8
Std. Err. Mean Diff.		1.37	1.80	1.04	.91	.79	.85	1.0	1.61
II, V, VI	Full	35.2	26.7	22.5	32.9	21.3	47.0	49.4	40.3
Duroc	Ltd.	42.4	38.5	23.9	37.5	25.6	51.5	53.6	47.3

* $P \leq .05$
** $P \leq .01$

stimulus for muscle and bone growth, thus leaving less energy for storage as fat.

The exact physiological mechanisms that are involved in the increased metabolic efficiency of crosses cannot be determined from this investigation. However, these data indicated that no important differences existed in digestibility. The present results suggest that energy losses through Specific Dynamic Action may be lower for crosses than for inbreds at the same level of feed intake, or possibly that inbreds and crosses differ in maintenance requirements.

More fundamental studies of the metabolic processes operative in the expression of hybrid vigor are essential before the nature of the heterosis effects can be determined more precisely.

SUMMARY AND CONCLUSIONS

The nature of heterosis effects on rate and economy of gains, digestibility and carcass composition was studied by comparing crosses with parental groups under full-feeding and also under equalized feed intake per unit live weight. The general effects of limited feeding also were investigated.

Sixteen representative pigs were selected at weaning from 3 or 4 litters in each of eleven breeding groups. The groups represented were two inbred lines of Poland Chinas and one of Hampshires, non-inbred Durocs, their six crosses and Poland China linecross gilts mated to Duroc boars. Each group was divided into two lots of eight pigs, equalizing sex, litter and initial weight as well as possible. One lot was full-fed and the other lot was limited-fed. The limited-fed linecross, topcross and outbred Duroc pigs were fed at the same level per unit of live weight as the full-fed parental inbred lines. All pigs were slaughtered at a live weight of about 205 pounds. Carcasses were evaluated from yields and scores of wholesale cuts and from dimensions indicating composition.

Within breeding groups, limiting feed intake per unit live weight to an average of 87 per cent of that under full-feeding caused no detectable change in digestibility of dry matter, 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, and with 6 per cent higher scores for quality. Limited feeding reduced dressing percentage enough to cancel the superiority of carcass quality so that no average advantage in net carcass value per unit of live weight could be credited to limited feeding. However, limited feeding did result in a marked improvement in net carcass value in those breeding groups that tended to yield the fattest carcasses, indicating that this fatness was due largely to their inherently larger appetites. The greater muscular development by the limited-fed pigs was explained by the increase of two weeks in their age at slaughter. The limited ration apparently did not retard growth of muscle and bone.

The Line V Hampshires were inferior as inbreds and were only average in crosses for rate and economy of gain; however, both the inbreds and crosses of Line V were superior in yields and scores of preferred wholesale cuts. The outbred Durocs gave relatively good performance in rate and economy of gain; however, their carcasses were excessively fat with poor muscle development. The topcrosses did not excel the outbred Durocs in rate and economy of gain; however, they approached the superior inbred lines in net carcass value.

In the full-fed linecrosses and topcrosses, hybrid vigor expressed itself in greater feed consumption (7 and 2 per cent, respectively) and in more rapid and more economical gains (30 and 13 per cent faster gain and 9 and 7 per cent less feed per unit gain, respectively); however, there were no differences in digestibility of the ration. Linecrosses between breeds gave much more rapid and more economical gains than linecrosses within breeds. There was little difference between the full-fed linecrosses and the full-fed inbreds in net carcass value; however, the topcrosses yielded carcasses that were definitely superior to the mean of the parental groups. The full-fed linecrosses dressed slightly higher but their carcasses contained less muscle and more fat, and no more net value than the full-fed inbreds. The poor health and depressed appetite of the full-fed Line V stock probably exaggerated the lack of fatness for the full-fed inbreds. The full-fed topcrosses yielded carcasses with greater muscular development and less fat than the mean of the parental groups. These results indicate that heterosis manifests itself through accelerated true growth (i.e., of muscle and bone) accompanied by increased appetite and more efficient utilization of food energy.

Even when restricted to the same level of feed intake as the full-fed inbred lines, the linecross and topcross pigs gained faster (by 13 and 26 per cent, respectively) and more economically (by 9 and 19 per cent, respectively) with no difference in ability to digest the ration and very small differences in carcass composition. Compared with the mean of the two parent lines (i.e., an inbred line and the outbred Durocs) at the same level of feed intake, the topcross pigs gained 10 per cent more rapidly, required 10 per cent less feed and showed a marked superiority in net carcass value per unit of live weight. Their carcasses contained less fat and more muscular tissue than the mean of the parental groups.

It is clear that hybrid vigor produces a greater stimulus for growth of muscle and bone and that a more efficient metabolic system permits the expression of this stimulus even without increasing rate of feed consumption. Since heterosis did not affect digestibility, it appears that this greater efficiency of crosses may be ascribed to reduced energy losses through Specific Dynamic Action or to lower maintenance requirements. More fundamental studies of the metabolic processes operative in the expression of hybrid vigor are essential before the nature of the heterosis effects can be determined more precisely.

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APPENDIX

Tables 19 to 29 inclusive, supplementing the data reported and discussed on pages 14 to 39.

TABLE 19 -- MEAN PERFORMANCE OF ALL PIGS PRIOR TO WEANING LISTED BY BREEDING GROUPS

Breeding	No. Litters	Avg. No. Farrowed Alive Per Litter	No. Pigs at 56 Days	Avg. No. Wn'd/ Litter	Avg. Weaning Wt./Pig
II	4	9.25	23	5.75	27.68
VI	4	7.00	14	3.50	31.96
V	3	8.33	19	6.33	25.46
II x VI	4	6.50	24	6.00	35.40
II x V	4	6.75	21	5.25	35.22
VI x V	4	7.25	22	5.50	32.49
II x D	3	9.67	23	7.67	30.43
VI x D	4	9.50	30	7.50	29.72
V x D	3	7.67	20	6.67	28.79
D x (II x VI)	4	8.50	32	8.00	31.12
Duroc	4	8.25	25	6.25	29.29

TABLE 20 -- COMPOSITION OF RATION FED DURING DIGESTION TRIALS--DRY BASIS

% Protein	% Crude Fiber	% Fat	% Ash	% Cr_2O_3	% N.F.E.
19.95	3.73	4.26	5.64	.55	65.87

TABLE 21 -- DIGESTIBILITY OF RATION USING "CHROMIUM OXIDE RATIO TECHNIQUE" BY FEEDING LEVELS FOR EACH LINE AND CROSS.

Trial 1: Collections 12/29/49 through 1/2/50.

Breeding	Feed Level	Protein	Crude Fiber	Fat	N.F.E.	Dry Matter
II	Full	73.90	23.64	63.86	89.67	79.28
	Ltd.	73.88	22.53	60.02	88.80	77.48
VI	Full	73.23	26.26	58.25	90.10	79.18
	Ltd.	71.03	33.02	50.43	91.82	79.78
V	Full	70.13	22.59	54.72	90.15	78.17
	Ltd.	70.04	22.98	48.30	90.83	78.00
II x VI	Full	70.26	20.89	59.75	89.22	77.48
	Ltd.	70.98	27.68	47.73	91.43	78.99
II x V	Full	71.19	23.43	58.38	90.27	78.79
	Ltd.	75.10	27.51	64.52	89.07	78.09
V x VI	Full	70.57	28.31	53.75	90.89	79.08
	Ltd.	71.89	32.08	54.27	90.93	79.08
II x D	Full	73.80	29.16	65.09	90.60	80.18
	Ltd.	72.42	23.52	61.73	90.79	79.19
VI x D	Full	69.44	18.34	50.61	90.32	77.99
	Ltd.	76.48	26.11	68.97	89.66	79.60
V x D	Full	71.20	30.70	52.24	91.68	79.58
	Ltd.	71.83	29.25	51.93	91.18	78.90
D x (II x VI)	Full	71.39	25.43	59.64	89.91	78.88
	Ltd.	74.52	23.91	67.51	90.12	79.18
Duroc	Full	72.74	25.12	55.44	89.95	78.79
	Ltd.	74.86	22.96	59.92	90.79	79.88
Means	Full	71.62	24.90	57.43	90.25	78.85‡
	Ltd.	73.00	26.50	57.76	90.49	78.92

‡Digestibility of ash appeared lower by 7% under limited feeding, presumably due to proportionately greater consumption of the mineral supplement, which was not included in feed analysis.

TABLE 23 -- ANALYSIS OF VARIANCE OF DIGESTIBILITY OF DRY MATTER

Source	D.F.	S.Sq.	M.S.
Total	43	50.60	
Levels	1	5.05	5.05
Groups	10	9.64	.96
Trials	1	.27	.27
L x G	10	17.05	1.70
L x T	1	6.12	6.12**
G x T	10	6.69	.67
L x G x T	10	5.78	.58

** $P \leq .01$

TABLE 22 -- DIGESTIBILITY OF RATION USING "CHROMIUM OXIDE RATIO TECHNIQUE" BY FEEDING LEVELS FOR EACH LINE AND CROSS.

Trial 2: Collections 2/16/50 through 2/20/50.

Breeding	Feed Level	Protein	Crude Fiber	Fat	N.F.E.	Dry Matter
II	Full	74.23	24.52	77.22	89.04	79.40
	Ltd.	70.64	5.17	65.63	88.76	77.11
VI	Full	69.65	28.24	54.17	89.61	77.69
	Ltd.	71.53	19.63	59.85	90.13	78.40
V	Full	73.84	30.27	70.83	89.76	79.79
	Ltd.	70.87	21.30	62.79	89.12	77.81
II x VI	Full	71.38	29.04	72.57	88.55	77.92
	Ltd.	72.48	25.57	67.81	89.19	78.60
II x V	Full	74.91	35.19	78.92	89.94	80.69
	Ltd.	69.38	1.91	69.74	87.90	75.99
V x VI	Full	76.33	41.28	73.02	91.46	82.21
	Ltd.	71.86	15.98	62.59	89.80	78.20
II x D	Full	73.83	30.80	73.70	89.56	79.60
	Ltd.	73.75	15.39	68.62	89.47	78.91
VI x D	Full	70.71	29.64	60.26	90.77	79.30
	Ltd.	71.64	21.38	64.77	89.44	78.39
V x D	Full	71.02	30.09	60.86	89.98	79.00
	Ltd.	71.54	1.04	66.28	88.25	76.42
D x (II x VI)	Full	73.23	29.05	75.73	89.50	79.50
	Ltd.	74.19	26.03	66.67	89.94	79.61
Duroc	Full	72.93	26.35	61.01	89.65	78.82
	Ltd.	73.58	18.80	73.75	89.10	78.80
Means	Full	72.91	30.41	68.94	89.80	79.45
	Ltd.	71.95	15.65	66.23	89.19	78.02

TABLE 24 -- ANALYSIS OF VARIANCE OF PERFORMANCE ITEMS AND CARCASS MERIT (Mean Squares Only)

Source of Variation	D.F.		Avg. Daily Gain/ Pig	Age Off Expt. (days)	D.F.		Dress-ing %	Loin Equiv. % Ch. Car. Wt. Unadj.	Loin Equiv. % Ch. Car. Wt. Adj.	Loin Equiv. % Live Wt. Unadj.	Loin Equiv. % Live Wt. Adj.	Mean Wt'd Score H.,L. Sh., Belly	Feed/Gain x 100 Pounds‡
Groups	10		.304**	4064**	10		6.47*	15.71**	182.7**	9.56**	92.4**	3.20**	13052**
Inbreds vs. Non-Inbred Groups		1	1.64**	22151**		1	11.61*	19.81**	183.5**	1.06	53.6*	2.73*	33267**
Between Inbred Lines		2	.422**	5246**		2	5.10	7.48	86.0*	9.96**	60.7**	1.32	27612**
Between Non-Inbred Groups		7	.079*	1143		7	6.12*	17.47**	210.3**	10.65**	106.9**	3.80**	6004**
Levels	1		.701	10297**	1		163.98**	26.01**	166.9**	20.50**	.2	2.24*	37170**
Levels x Groups	10		.022	280	10		3.50	2.52	15.5	1.24	7.6	.23	2908**
L x Inbr. Effect		1	.012			1	8.71*						138
L x Lines Wn. Inbreds		2	.020			2	0						1362
L x Non-Inbr. Groups		7	.024			7	3.81						3745**
Litters Wn. Levels and Groups	58		.030	619	57		2.74	2.52	25.2	1.85	12.1	.45	(1408)‡
Wn. Litters, Levels and Groups	82		.033	223	80		1.87	2.23	17.7	1.52	9.3	.37	(820)‡

* P ≤ .05
** P ≤ .01

‡ Based on 419 degrees of freedom between Duroc hogs fed individually from 72 days of age to a final weight of 225 pounds at the Alabama Experiment Station, and on 111 degrees of freedom between litter within line and season for Iowa Poland data (Dickerson, 1947) when the mean number of pigs per litter within levels is 2.

TABLE 25 -- ANALYSIS OF VARIANCE OF ITEMS INDICATING CONFORMATION AND MUSCLING
(Mean Squares Only)

Source of Variation	D.F.		B.L. (mm.)	L.L. (mm.)	Est. % Lean of Ch. Car. Weight (Mc-Meekan)	Loin WxD (cm^2.)	Ham WxD (cm^2.)	% of Chilled Carcass Weight: Lean Cuts: Ham, Loin, and Sh.	Ham, Loin, Sh. and L.T.	Bone
Groups	10		2965**	929**	148.00**	189.0**	454.3**	44.86**	65.93	1.46**
Inbreds vs. Non-Inbred Groups		1	2794**	504	324.14**	45.3	509.9	77.00**	92.73	3.20**
Between Inbred Lines		2	5444**	501	16.48	99.7	44.8	17.88	16.62	.46
Between Non-Inbred Groups		7	2281**	1112**	160.42**	235.1**	563.3**	47.97**	76.18	1.50**
Levels	1		221	2304*	309.94*	233.4*	19.5	109.83**	190.05**	.48
Levels x Groups	10		308	333	35.93	45.0	48.6	6.34*	12.91**	.31
L x Inbr. Effect		1		698	142.22**	207.9*	28.8	25.88**	59.37**	
L x Lines Wn. Inbreds		2		326	29.34	31.9	13.8	9.68	10.92	
L x Non-Inbred Groups		7		282	22.63	25.5	61.3	2.59	6.85	
Litters Wn. Levels and Groups	57		296	208	24.98	41.6	127.5	6.61	45.26	.29
Wn. Litters, Levels and Groups	80		419	188	19.98	36.0	69.1	3.15	4.37	.26

* P ≤ .05
** P ≤ .01

TABLE 27 -- ANALYSIS OF VARIANCE OF DIFFERENCES BETWEEN CROSSES AND PARENTAL MEANS (MEAN SQUARES ONLY)
Rate and Economy of Gains and Carcass Merit.

Source of Variation	D.F.	Avg. Daily Gain /Pig	Feed Req. /Cwt. Gain	Age Off Expt. (days)	Dressing %	Loin Equiv. % Ch. Car. Wt.: Unadj.	Adj.	Loin Equiv. % Live Wt.: Unadj.	Adj.	Mean Wt'd Score
Full-Fed										
Linecrosses:										
Heterosis	1	.85**	16945	14043**	19.03*	8.98	89.9	.50	13.2	1.17
Het. x Cross	2	.38**	7874	1899	6.68	2.66	33.5	3.76	32.6	.88
Topcrosses:										
Heterosis	1	.23**	8883	1274	.64	2.12	102.5*	1.74	58.9*	2.95*
Het. x Cross	2	.06	10426	2137*	.33	1.61	8.4	.76	4.1	.15
Equal Feed Intake										
Linecrosses:										
Heterosis	1	.18*	17765	1748	3.38	.96	4.0	3.14	6.73	.01
Het. x Cross	2	.26**	14518	2806*	4.13	.79	4.1	3.95	7.08	.09
Topcrosses Compared With Inbr. Parents:										
Heterosis	1	.57**	63381**	3317*	40.1**	.07	3.98	18.76**	33.6	.06
Het. x Cross	3	.01	2830	1100	.68	.61	5.50	.72	3.0	.11
Topcrosses Compared With Mean of Parents:										
Heterosis	1	.12*	16209*	746	38.0**	10.9*	126.7*	2.74	13.97	2.19*
Het. x Cross	2	.02	734	745	.74	1.2	13.5	.10	4.32	.25
Litters Wn. Levels and Groups	58‡	.03		619	2.74	2.52	25.16	1.85	12.11	.45

‡ 57 for carcass data.

* P ≤ .05
** P ≤ .01

TABLE 26 -- ANALYSIS OF VARIANCE OF ITEMS INDICATING FATNESS
(Mean Squares Only)

Source of Variation	D.F.	Mean B.F. Th. (mm.)	Th. of Fat on Ham (mm.)	Belly Th. in Flank (mm.)	% F.B., F.T., L.F., Belly of Ch. Car.	% F.B., F.T., and L.F. of Ch. Car. Weight	Est. % Fat in Edible Portion of Carcass (Hankins)	Est. % Fat in Edible Portion of Carcass (Warner)	Est. % Fat of Ch. Car. Wt. (McMeekan)
Groups	10	219.55**	390.60**	19.70	79.48**	56.42**	84.65**	80.00**	179.2**
Inbreds vs. Non-Inbred Groups	1	440.95**	332.00**	13.00	112.59**	76.38**	170.12**	63.79*	407.8**
Between Inbred Lines	2	24.66	29.00	28.00	23.12	20.05	9.49	12.80	1.4
Between Non-Inbred Groups	7	243.60**	502.00**	18.40	90.86**	63.95**	93.91**	101.51**	197.4**
Levels	1	229.68**	178.00*	107.00**	167.32**	84.67*	88.54**	122.92**	85.0*
Levels x Groups	10	19.63	33.50	4.80	11.15	10.02*	7.57	11.60	9.7
L x Inbr. Effect	1	35.96	45.00		53.00**	50.04**			
L x Lines Wn. Inbreds	2	22.11	33.50		16.72	12.39			
L x Non-Inbred Groups	7	16.59	31.86		3.56	3.63			
Litters Wn. Levels and Groups	57	21.52	36.82	12.42	9.47	7.20	8.31	11.41	29.6
Wn. Litters, Levels and Groups	80	12.96	22.05	8.12	5.93	4.64	4.99	8.14	11.9

* $P \leq .05$
** $P \leq .01$

TABLE 28 -- ANALYSIS OF VARIANCE OF DIFFERENCES BETWEEN CROSSES AND PARENTAL MEANS (MEAN SQUARES ONLY)
Conformation and Muscling.

Source of Variation	D.F.	B.L. (mm.)	L.L. (mm.)	Est. % Lean of Ch. Car. Weight (McMeekan)	Loin WxD (cm^2.)	Ham WxD (cm^2.)	% of Ch. Carcass: Ham, Loin, Sh.	% of Ch. Carcass: Ham, Loin, Sh. and L.T.	Bone
Full-Fed									
Linecrosses:									
Heterosis	1	44.4	196	268**	110	2.2	30.7*	85.6	1.34*
Het. x Cross	2	102.7	525	68	93	251.9	4.1	57.9	1.25*
Topcrosses:									
Heterosis	1	323.1	571.4	17.6	103.2	288.7	11.2	29.7	.16
Het. x Cross	2	87.2	831.1*	33.6	28.7	47.9	7.2	6.9	.63
Equal Feed Intake									
Linecrosses:									
Heterosis	1	4.2	209.9	5.0	0.11	28.34	.07	.16	1.46*
Het. x Cross	2	1.8	391.2	2.0	16.0	11.50	6.18	7.32	.71
Topcrosses Compared With Inbr. Parents:									
Heterosis	1	2995**	10.5	8.3	15.8	78.3	.19	1.0	.01
Het. x Cross	2	655	87.0	5.2	21.0	48.3	.91	1.7	.48
Topcrosses Compared With Mean of Parents:									
Heterosis	1	1426*	1.5	165.1*	328.2**	253.5	25.1	53.8	2.0*
Het. x Cross	2	186	37.7	16.7	2.7	69.1	1.9	6.6	.55
Litters Wn. Levels and Groups	57	296	208	25.0	41.6	127.5	6.6	45.3	.29

* $P \leq .05$
** $P \leq .01$

TABLE 29 -- ANALYSIS OF VARIANCE OF DIFFERENCES BETWEEN CROSSES AND PARENTAL MEANS (MEAN SQUARES ONLY)
Fatness.

Source of Variation	D.F.	Mean B.F. Th. (mm.)	Th. of Fat on Ham (mm.)	Belly Th. in Flank (mm.)	% F.B., F.T., L.F., and Belly of Ch. Car. Wt.	% F.B., F.T., and L.F.	Est. % Fat in Edible Portion of Carcass (Hankins)	Est. % Fat in Edible Portion of Carcass (Warner)	Est. % Fat of Ch. Car. Weight (McMeekan)
Full-Fed									
Linecrosses:									
Heterosis	1	116.9*	68.0	27.6	61.0*	43.4*	45.3*	15.9	53.1
Het. x Cross	2	51.2	78.9	7.2	32.5*	23.3*	19.8	42.3*	42.4
Topcrosses:									
Heterosis	1	101.9*	152.2*	36.8	34.9	20.9	41.4*	45.3	54.0
Het. x Cross	2	69.1*	86.1	14.3	8.9	4.5	25.8	16.6	82.0
Equal Feed Intake									
Linecrosses:									
Heterosis	1	36.6	8.8	1.0	3.3	7.8	14.3	22.6	9.2
Het. x Cross	2	5.4	37.5	3.6	11.1	4.2	2.2	5.9	57.6
Topcrosses Compared With Inbr. Parents:									
Heterosis	1	8.1	.003	14.6	1.1	.02	3.12	8.87	78.6
Het. x Cross	2	16.8	6.90	11.9	4.1	4.30	5.85	12.47	36.8
Topcrosses Compared With Mean of Parents:									
Heterosis	1	86.8*	404.3**	38.6	77.4**	51.0*	33.9*	104.2**	7.52
Het. x Cross	2	67.7	46.5	8.1	10.3	6.8	23.8	24.3	66.1
Litters Wn. Levels and Groups	57	21.5	36.8	12.4	9.5	7.2	8.31	11.4	29.6

* $P \leq .05$
** $P \leq .01$