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# A Study of Factors Related to Carcass Yields in Swine

J. N. Cummings and L. M. Winters  
Division of Animal Husbandry

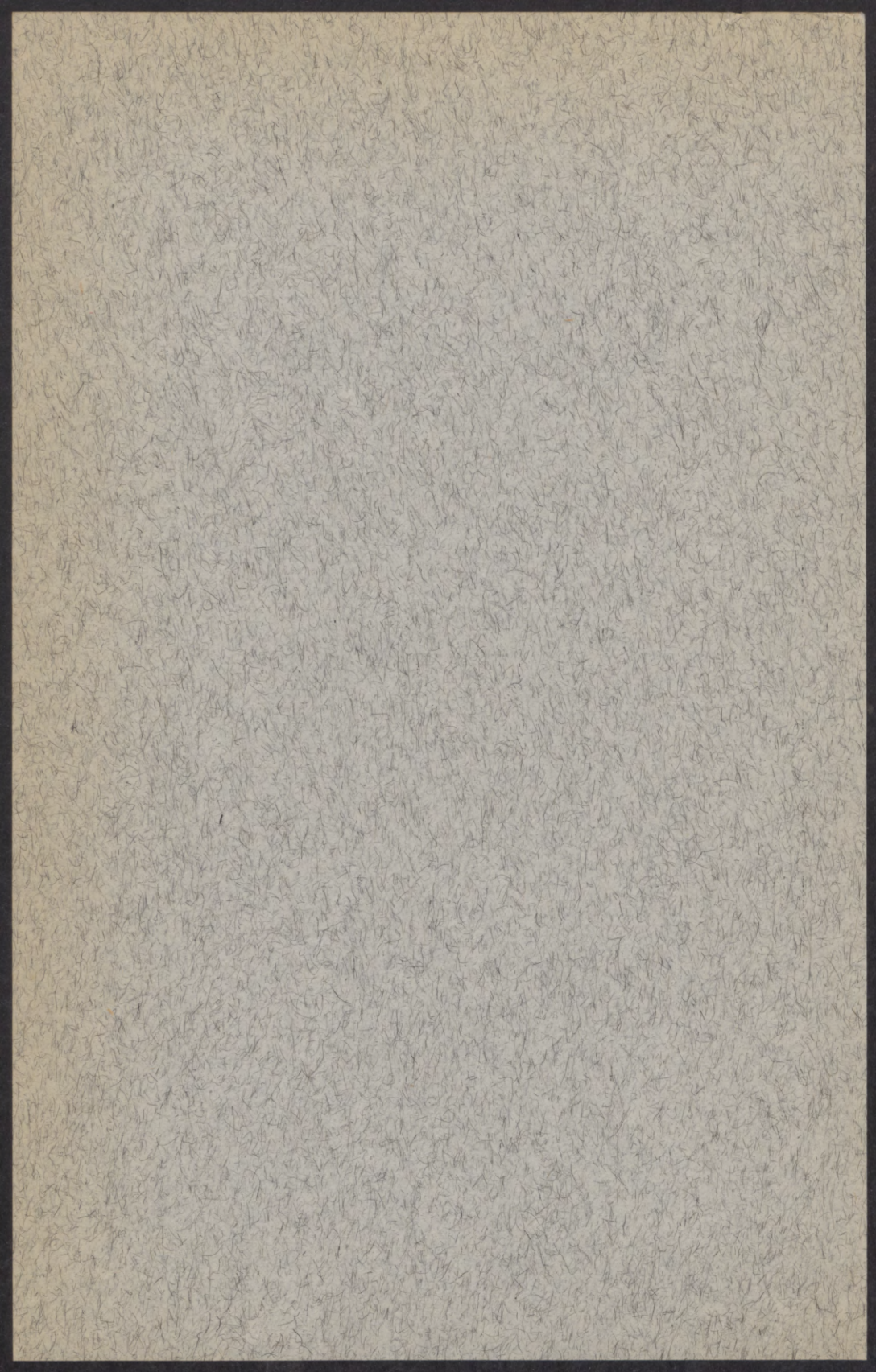


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## CONTENTS

	Page
Introduction .....	3
Objectives .....	6
Materials and methods .....	6
Source of data .....	6
Method of slaughtering and dressing the hogs .....	8
Carcass measurements .....	10
Method of cutting the carcasses .....	10
Calculation of the carcass yields .....	13
I. The effects of breeding on carcass characteristics .....	13
Literature .....	13
Experimental .....	20
II. The effects of plane of nutrition on carcass characteristics .....	23
Literature .....	23
Experimental .....	27
III. Relationships between carcass measurements and yields .....	29
Literature .....	29
Experimental .....	33
IV. Relationships between rate of growth and carcass characteristics .....	39
Literature .....	39
Experimental .....	41
V. Use of the T factor to predict the yield of the five primal cuts .....	52
Discussion of the results .....	54
Summary and conclusions .....	59
Literature cited .....	62

# A Study of Factors Related to Carcass Yields in Swine<sup>1</sup>

J. N. Cummings and L. M. Winters<sup>2</sup>

**D**URING THE YEARS preceding World War I the greatest use of the pig in this country was in the conversion of a large share of the mammoth corn crop into lard which at that time was the main cooking fat used. At the same time the United States was enjoying the benefits of a large export trade for lard in foreign countries.

But by 1923 methods of hydrogenating vegetable oils had been developed and products containing these oils were made available in a form quite satisfactory for cooking purposes and at a very reasonable cost. World War I destroyed our export trade for lard, and since that time the demand for lard in this country has been gradually declining. In turn, vegetable fat preparations have replaced lard to the point that lard is now a by-product of the pork industry instead of a main product. Processors are now selling lard at a lower price than they pay for live hogs.

To keep up with these changes in demand, the pork industry has shifted its main attention to the processing and improvement of the fleshy portions of

the carcass. In the United States these portions are classified generally into "five primal cuts," which include (1) regular hams, (2) bellies or bacon, (3) loins, (4) Boston butts, and (5) shoulder picnics or picnic hams.

As a result of this shift the general public has learned to like fresh and cured pork more than when lard was the main product from the pig. Nevertheless, it is doubtful that the major portion of the hog raisers in this country have adjusted to this change as well as they should.

Two general methods are available for altering the composition of the hog: (1) improvements in environmental factors such as management and feeding practices and (2) improvements or

<sup>1</sup> A large portion of the data for this study was taken from the Minnesota swine breeding project conducted in cooperation with the Regional Swine Breeding Laboratory, Ames, Iowa, Bureau of Animal Industry, USDA. Material for this publication has been taken from a thesis submitted by the senior author to the Graduate Faculty of the University of Minnesota in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

<sup>2</sup> The authors are indebted to the personnel of Wilson & Co., Inc., Albert Lea, Minnesota, for their constant help and splendid cooperation in collecting the slaughter and cut-out data.

alterations through breeding. Both methods have been used and have been effective in altering swine type as far as they have gone. Yet even though considerable advancement has been made in techniques, these methods are still time consuming and require much forethought to be used effectively in keeping pace with further changes in demand.

The one factor needed most for a more precise method of improving our hogs is a standard of perfection for carcass quality. The yield of the five primal cuts expressed as a percentage of the cold carcass is probably the best single appraisal, yet this standard is subject to considerable error because of differences in quality of the carcass.

In Canada, England, and Denmark more specific standards than those used in the United States have been established for hog carcass quality, but these standards apply solely to the British market. We might well use some of their points of appraisal in varying degrees. Yet the fact still remains that the British demands for high quality pork are not exactly the same as they are in this country, even though we have shifted our demands in somewhat the same direction.

The external appearance of the live hog, as in the case of all our meat animals, is often quite misleading in predicting its internal composition. On the other hand, it is still impossible to appraise potential breeding animals on the basis of their own carcass composition without slaughtering them.

However, an indirect method of selection for carcass traits has been used; that is, selection on the basis of progeny slaughter tests (the Danish and Canadian systems). An alternative is to establish inbred lines from ancestors with known carcass quality and take samples from within these lines and their crosses. The latter procedure has been used in furnishing much of the data used in the following study.

The main objective of the swine breeding project at the Minnesota Agricultural Experiment Station has been the improvement of swine in characteristics of greatest economic importance. This has been attempted by developing and testing the various systems of breeding (Winters, *et al.*, 28 and 29).

The accomplishments so far have been the development of inbred lines within the Poland China breed and within two crossbred foundations (Minnesota No. 1 and Minnesota No. 2), and the crossing of these inbred lines in various combinations.

The traits emphasized as a basis for selection have been these: (1) fertility, (2) survival of the young, (3) rapid rate of gain from weaning to market weight, (4) economy of feed utilization, and (5) desirability of the product (the type of carcass and quality of pork produced).

The first four characteristics are of most direct benefit to the hog producer. The fifth characteristic is of great importance to any group involved in pork production, from producer to consumer. Naturally, satisfaction on the part of the consumer is necessary to maintain a thriving pork industry.

Only indirect methods have been applied in the selection of a better quality pork carcass so far in the Minnesota project. One of the methods involved selection of a type of hog which did not necessarily follow ideas of external appearance most widely accepted in show ring competition. This departure was made because it seemed more reasonable that a long-bodied, fleshy hog (without extreme width due to excess backfat), with wide full hams and smooth sides should give a higher yield of the primal cuts than short, chuffy types. More important than this, however, was the fact that foundation stock for two of the lines in particular (Minnesota No. 1 and Minnesota No. 2) was selected from well-established breeds already known to have good bacon

qualities and a tendency to produce a small amount of lard.

Up to the time the data were collected for this study, only general observations on carcass quality had been made — and these from occasional slaughters of only a few pigs at a time. Since then as the opportunity has presented itself, hogs from the various groups represented, have been slaughtered under relatively uniform procedures and the cut-out data collected. These data have so far shown only the cut-out value of the different hogs; measures of the true quality of the meat itself have not been available.

Davidson *et al.* (8) have prepared a system of scoring pork and bacon carcasses with an established ideal that comes closest to satisfying the British trade. Under their system actual measurements of the various parts of the carcass are used as far as possible rather than the "eye impression."

They also found that it was necessary to cut through the carcass at right angles to the backbone near the region of the last rib, and score the amount of lean in the "streak" and measure the "eye muscle" of the loin in order to obtain a satisfactory appraisal of the fleshing qualities in the entire carcass.

The score cards they developed also take into account differences in carcass weight. This scoring system is used mainly for carcass competitions; there, photographs of the cuts as well as measurements and scores are returned to exhibitors to show them exactly what they had produced in comparison with what was wanted in the British trade.

From studying the composition of the body of the pig at various stages of growth from birth to 200 pounds, McMeekan (17, 18, 19, and 20), and McMeekan and Hammond (21 and 22) found that changes in form and composition of the animal are the result of orderly changes in the proportions of differentially growing parts.

Their findings may be summarized as follows: the pig conforms to a centripetal growth gradient diagram. At birth the body is short and shallow, with the head, neck, and legs high in proportion to the loin. Then the loin lengthens out, increasing the proportion of loin to the head and neck. Later the body deepens and thickens so that the head and lower parts of the legs are small in relation to the rest of the body.

These changes are brought about by waves of growth which start at the six extremities—head, tail, and four feet—and spread to meet in the lumbar region, the latest maturing part of the body. The authors found that gradients existed not only within tissue groups, but also among them, and that changes in form and composition were due to both gradients.

These authors also found that the skeleton proportionately increased the least during the first seven months following birth; muscle and fat increased the most. Also, the skeleton developed first, followed by muscle and later by fat. The skeletal units of the head and trunk showed an anterior-posterior growth gradient in their order of development, while the bones of each limb showed a centripetal gradient, the upper units developing later than the lower units. And to a very marked degree both muscle and fat grew and increased in weight with gradients similar to the skeletal units they surrounded.

The authors noted, too, that variability appeared to be affected by the rate of development of the character concerned: late-developing characters in general tended to be more variable than early ones. Speeding up and slowing down the growth rate as a whole affected the late developing parts of the pig the most, while the stage of growth at which the rate was varied affected the nature and extent of the response.

These same workers also showed other interesting growth relationships within bones and muscles. The increase in weight of bones was accounted for first by increase in length and later by increase in diameter. Histological studies of the changes in muscles showed that the increase in the size of muscle fiber was sufficient to account for the entire increase in the mass of muscle. There was no evidence of any increase in the number of muscle fibers during postnatal life.

The body organs and offals also showed marked heterogenic growth, these authors found. Those parts, essential to the life processes and body functions, appeared relatively well developed at birth and made a smaller proportional amount of growth in postnatal life than the body as a whole. Those organs associated most intimately with growth functions grew proportionately most from birth. Those organs having a function primarily of storing nutrient reserves developed during later stages of growth.

Hammond (11) postulated that differences in types and breeds of sheep and hogs are due mainly to different intensities in the various phases of normal growth, and these differences in rate are established by hereditary limitations. He characterized the lard

type pig by poor development of those parts which grow early in life and by the intensive development of the parts which grow later. The bacon type, on the other hand, he characterized by intensive development of the tissues which grow early (skeletal and muscular framework), and the reduction to a minimum of the later growing parts (fat).

## Objectives

The objectives of the studies in this bulletin were these:

1. To compare the carcass characteristics of the various inbred lines and line crosses from the Minnesota swine breeding project with one another and with hogs from other sources to determine the effects of breeding on carcass quality.
2. To study the effects of the level of nutrition on carcass characteristics in swine from different genetic sources.
3. To determine the value of relatively simple carcass measurements for predicting the yield of the five primal cuts and the degree of fatness in swine carcasses.
4. To determine the effects of growth rate on carcass characteristics in pigs of different breeds.

## MATERIALS AND METHODS

### Source of Data

**F**ROM 1944 to 1948 slaughter data and carcass measurements were collected on 741 hogs. These hogs were killed, dressed, and the carcasses cut into the regular wholesale cuts by Wilson & Co. at Albert Lea, Minnesota. Of the 741 hogs complete slaughter and cutting data were obtained on 708 individually; one group of 33 hogs, selected

from the regular market run at the Albert Lea market, was handled as a single lot and no attempt was made to gather the data on individual hogs within the group.

The hogs came from a very wide variety of sources and breeding:

**1. Hogs from the Minnesota swine breeding project**—A total of 376 hogs was taken from the Minnesota Agricultural Experiment Station, which has been carrying on inbreeding and cross-

breeding experiments on swine in cooperation with the Regional Swine Breeding Laboratory. This number included Poland Chinas from nine inbred lines; crosses between five of the Poland China inbred lines; Minnesota No. 1's (an inbred line starting from a cross between the Tamworth and the Danish Landrace); Minnesota No. 2's (an inbred line originating from a cross between the Canadian Yorkshire and two inbred lines of Poland Chinas); crossbreds which resulted from mating Minnesota No. 1's with three different inbred Poland China lines; crossbreds between the Minnesota No. 2 and four different inbred Poland China lines; crossbreds between the Minnesota No. 1 and Minnesota No. 2; and crossbreds which resulted from rotational crossing of the Minnesota No. 1, the Minnesota No. 2, and one of the inbred Poland China lines.

These inbred lines and their crosses have been described by Winters *et al.* (28 and 29) and in this study will be designated as follows:

- A—the "A" line of Poland Chinas
- B—the "B" line of Poland Chinas
- BS—the Black Star line of Poland Chinas
- C—the "C" line of Poland Chinas
- C<sub>1</sub>, C<sub>2</sub>, and C<sub>3</sub>—the C<sub>1</sub>, C<sub>2</sub>, and C<sub>3</sub> lines of Poland Chinas
- M—the "M" line of Poland Chinas
- V—the Viola line of Poland Chinas
- WL—the Western Lady line of Poland Chinas
- No. 1—the Minnesota No. 1 line
- No. 2—the Minnesota No. 2 line
- 1-M, 1-V, 2-1, 2-M, 2-V-1, C-M, etc.—crossbreds involving the above inbred lines as indicated

Since the swine in the Minnesota project are raised at the different stations in the state, only certain lines and crosses are produced at a particular station. Some differences in environment probably exist among the stations, but there is no suitable means of measuring these differences exactly.

However, attempts are made to standardize feeding and managerial practices for all stations insofar as possible. It can be stated that all the hogs from the Minnesota swine breeding project were fed well-balanced rations at all times and were given full opportunity under the particular local conditions to grow rapidly from the time of birth until slaughter. The systems of management and rations used have been given by Winters *et al.* (28 and 29).

**2. Hogs from the outbred herd at the University of Minnesota**—Three groups of hogs, representing very good individuals from the three standard breeds (Poland China, Chester White, and Duroc Jersey), were taken from the University of Minnesota purebred herds. These herds are maintained separately from those in the swine breeding project and for years have been bred by orthodox methods of outbreeding within the breed itself. They are fed on standard hog rations and given maximum opportunity for growth and development from birth to slaughter.

In this study the three groups are designated as outbred PC, outbred CW, and outbred DJ, or merely as PC, CW, and DJ. All of these hogs were from spring litters farrowed in 1947.

**3. Hogs from selected market runs**—These hogs were picked by the men at the Albert Lea market from the better end of the general run of butcher hogs coming into that market. Groups were selected on three different occasions (October, 1945; July, 1946; and January, 1947) and represented the various types of breeding used by the farmers in that area.

As mentioned above, the first group was killed and cut as a single lot and data were not recorded for the individual hog. This group is designated as "selected market run—1." Carcass data were gathered on each hog in the other two groups and hence could be used

in further analyses, which will be reported later. The two latter groups are labeled as one, "selected market run—2."

**4. Hogs from the Schechter herd—**One group of 34 hogs from the herd of J. Ray Schechter at Worthington, Minnesota, were used in this study. They had been farrowed in the spring of 1947 and averaged approximately 200 pounds market weight. These pigs were Minnesota No. 1 top-crosses from a herd in which crossbreeding had been used continuously for many generations. Purebred boars of different breeds were used in the following order: Poland China, Chester White, Berkshire, Poland China, Spotted Poland China, Poland China, and Minnesota No. 1.

**5. Hogs from the self- and restricted-feeding trial—**Winters, Sierk, and Cummings (30) reported on a study designed to obtain further information on the effect of different levels of feed intake on economy of production and on carcass quality in swine. In this study 80 pigs belonging to the Poland China, Duroc Jersey, and Chester White breeds and taken from the University of Minnesota purebred herds were assigned to four lots of 20 pigs apiece and fed as indicated:

**Lot 1—**self-fed the entire feeding period

**Lot 2—**self-fed until the pigs weighed 125 pounds, then feed restricted to three per cent of body weight

**Lot 3—**feed restricted to three per cent of body weight until the pigs weighed 125 pounds, then self-fed to the finish

**Lot 4—**feed restricted to three per cent of body weight for the entire feeding period

The pigs were weighed weekly and the feed adjusted according to the above schedule. Each group was fed on pasture until the pasture season was over. Early in the experiment three pigs were removed from both

Lots 1 and 2 because of death or lack of thrift that apparently was not related to the experiment. Another pig in Lot 1 was lost to the experiment when carcass data on it were not obtainable after slaughter. Hence, the numbers were reduced to 16, 17, 20, and 20 pigs in Lots 1, 2, 3, and 4, respectively.

The rations fed were these:

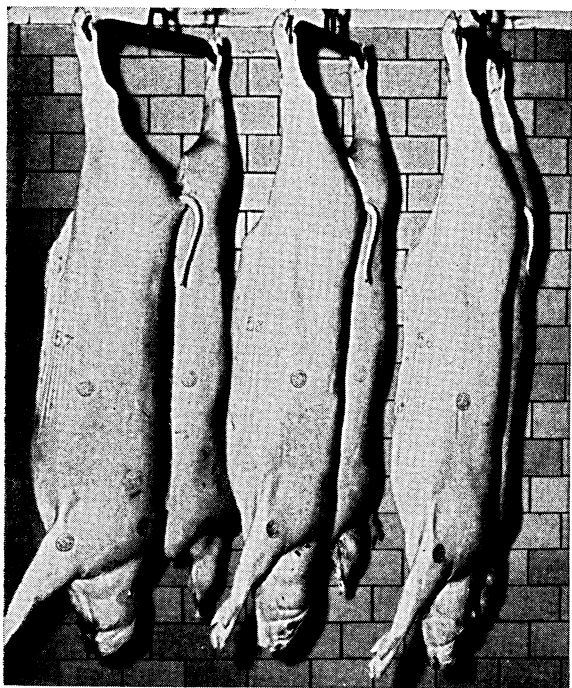
Ration	First 28 days	Second 28 days	Third 28 days	Dry lot period
	pounds	pounds	pounds	pounds
Corn .....	70	80	85	85
Ground oats .....	10	.....	.....	.....
Tankage .....	10	10	7.5	6.0
Soybean meal .....	10	10	7.5	6.0
Alfalfa meal .....	.....	.....	.....	8
Salt and limestone	1	1	1	1

The pigs from the above feeding trial were included in this work in order to study the effects of heredity and environment on the development of carcass characteristics. Because there were three different breeds subjected to four different treatments, the pigs were divided into 12 "breed groups," which are treated separately in many of the analyses to follow. The name of the breed and the number of the lot are included in the label for each group as follows:

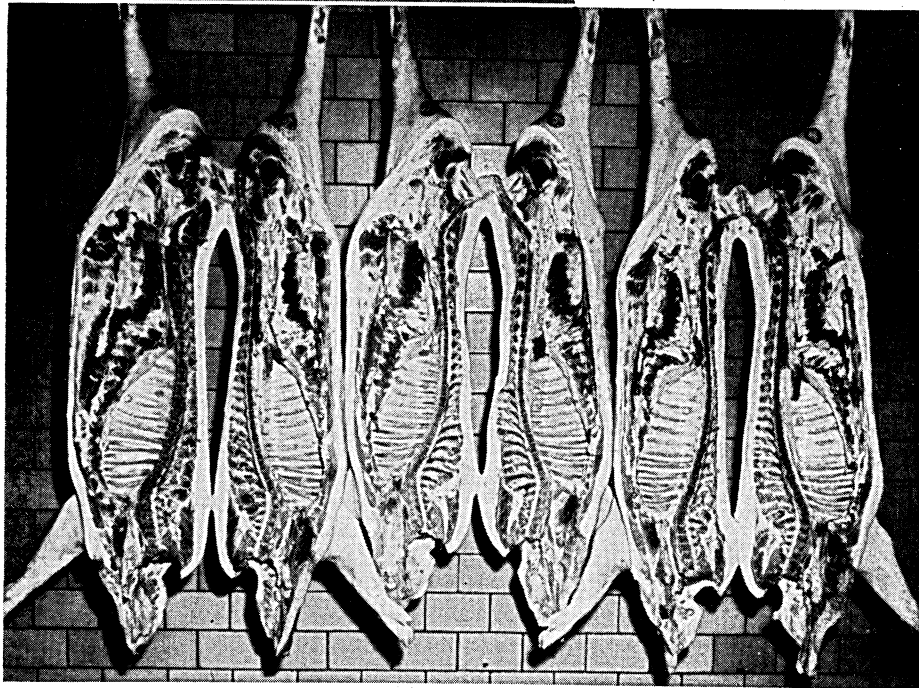
PC-1	CW-1	DJ-1
PC-2	CW-2	DJ-2
PC-3	CW-3	DJ-3
PC-4	CW-4	DJ-4

## Method of Slaughtering and Dressing the Hogs

All hogs used in this study were killed and processed by Wilson & Co. at its plant at Albert Lea, Minnesota. They were dressed packer style. That is, the head and viscera were removed and the jowls left on the carcass; each carcass was split in half through the center of the backbone; the kidneys were removed; the leaf fat was taken out and weighed separately; and the hams were faced (figures 1 and 2).



Figs. 1 and 2. Hog carcasses before cutting into wholesale cuts.



Each carcass was weighed individually while hot and again after being chilled for 24 hours. The cold carcass weight, however, was used as the basis on which the yields of the various wholesale cuts were determined and also the basis for determining dressing percentage.

However, the live weights of the hogs were subject to considerable error because the time at which they were taken varied greatly in relation to the time of slaughter. In some instances at the stations live weights were taken two days before slaughter. In other instances the live weights were taken just before slaughter.

Because of this difference, and because live weights are subject to additional error due to the variable amount of shrink or fill each hog may show in the yards, the importance of dressing percentages has been minimized and is not being included in most of the analyses. The above reasons also explain why the percentage yield of the different cuts has been based on cold carcass weight instead of live weight.

## Carcass Measurements

The following measurements were taken on each carcass after it was thoroughly chilled:

- B<sub>1</sub>—depth of the subcutaneous backfat at the thinnest part directly over the center of the vertebral processes
- B<sub>2</sub>—same as B<sub>1</sub> but at the thickest part; in some cases this measurement taken in the lumbar region and on other carcasses, taken over the shoulder
- B<sub>7</sub>—depth of the subcutaneous backfat directly over the center of the spinous process of the seventh thoracic vertebra
- B—average backfat thickness, determined by averaging B<sub>1</sub>, B<sub>2</sub>, and B<sub>7</sub>
- C—length of carcass, taken from the anterior border of the aitchbone

(pelvic bone) to the anterior border of the first rib midway between its upper and lower extremities

All measurements were taken in inches and tenths of inches, and the above symbols will be used to designate a particular characteristic in this study. Figure 3 shows where the measurements were taken.

## Method of Cutting the Carcasses

Before killing, each hog was identified with an individual number tattooed over the shoulder. Then after chilling, each wholesale cut was marked with the same number as the tattoo. As the carcasses went through the cutting room, each cut was weighed separately on tested scales at the various stations for cutting and thereby the weight of each wholesale cut was recorded individually for all hogs processed.

The authors believe that it is necessary to give as detailed and accurate an account of the cutting procedures as possible, if cutting tests made in the future or at other packing plants are compared with the results reported in this study. Though these hogs were cut over a period of more than three years, all groups were cut alike. Each carcass was cut into the following wholesale pork cuts:

1. **American-cut regular hams**—The ham was removed from the side by sawing on a slight slant, favoring the flank side where the pin bone begins to widen. (This point is approximately 2¼ inches from the aitchbone on hams under 12 pounds, 2¼ to 2½ inches from aitchbone on hams weighing 12 to 18 pounds, and from 2½ to 2¾ inches on still heavier hams.)

The cut was made straight down at a right angle to an imaginary line drawn from the center of the shank to the top of the aitchbone. After reaching the point where the ham flank is properly protected on the belly side,

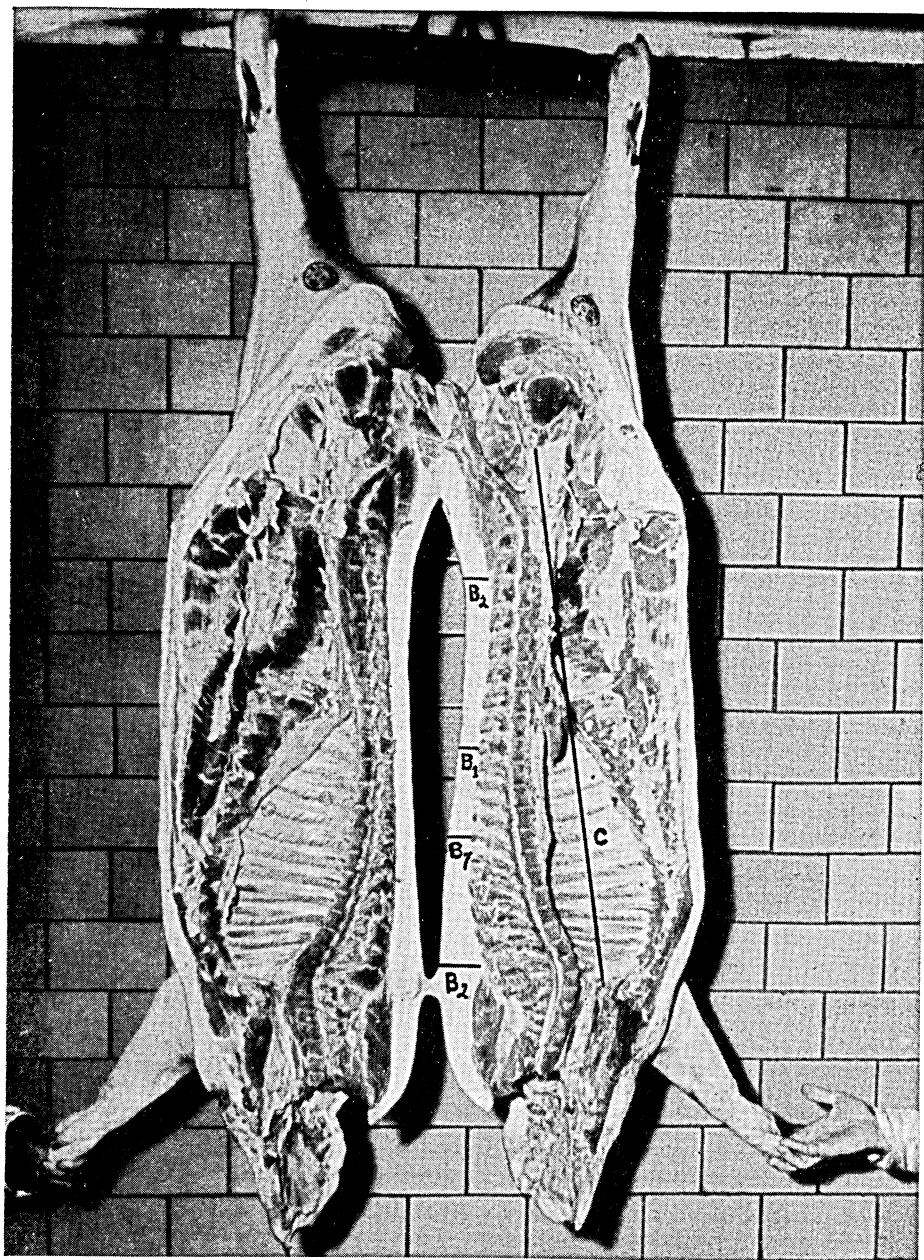


Fig. 3. Hog carcass showing points at which measurements were taken:  $B_1$ —backfat thickness at the thinnest part;  $B_2$ —backfat thickness at the thickest part;  $B_7$ —backfat thickness opposite the spinous process of the seventh thoracic vertebra;  $C$ —length of carcass.

the ham was cut off sharp and rounded so as to leave maximum flank on the belly and avoiding a sloping cut on the butt end to insure maximum flank on the belly.

The hind foot was removed from the ham by sawing through the upper part of the hock joint at a point where the marrow would not be exposed, and leaving a figure of an X in the exposed bone end. The tail bone was removed and the ragged edges of skin, fat, and lean trimmed off.

**2. Skinned hams**—Data were collected on skinned hams from only 349 of the hogs killed. Regular hams were trimmed into Board of Trade skinned hams by removing the skin down to four inches at the most from the shank. The amount of skin left should equal approximately 50 per cent of the skin. The fat was beveled on the butt end, and if the fat covering was over one inch thick the skinned surface was fattened down to one inch fat covering. The skin on the flank side of the ham was left about one inch longer than on the cushion side.

**3. Boston butts, picnics, jowls, and clear plates**—The shoulder was chopped from the side so as to leave two full ribs (counting the floating rib or breast rib) in the shoulder. The cut was made at a very slight slant away from the elbow, favoring the loin. The neck bone and first two ribs were then removed from the shoulder.

The standard shank Board of Trade picnics were made by removing the butt from the shoulder at the point above the blade bone joint where the blade bone begins to widen. At least one inch of the blade bone was left in the picnic. This point of cut is about one inch above the ends of the two large blood vessels (the brachial artery and vein) which are exposed when the neck bone is removed. The cut was made by sawing parallel to the top line to avoid making a wedge-shaped butt.

The front foot was removed at the upper knee joint so as not to expose the marrow. The picnics were trimmed by removing the breast flap, jowl, and any loose fat or lean, and by trimming full and well rounded. The fat was beveled on the skin side at the butt end.

The clear plate was separated from the Boston butt by removing in one piece all skin and surplus fat to within one-half inch thickness. The edges were then beveled and the clear plate was squared up at the neck end, leaving one-fourth to one-half inch of the ear pocket.

The jowls were trimmed by removing the breast flap, any thin and ragged edges, and any blood clots.

**4. Regular loins (blade in)**—Loins were scribed to  $1\frac{1}{4}$  to  $1\frac{1}{2}$  inches outside the point of chine straight toward the tail end. Each loin was then fattened (pulled from the side) to one-half inch fat covering at the most.

The spareribs were removed from the side, taking as little lean as possible and avoiding damage to the belly.

**5. Fatbacks**—The fatback was removed from the side, cutting  $1\frac{1}{2}$  inches toward the top line from the loin scribe mark and favoring the belly. The surplus lean was removed at the shoulder end, and the tail end was squared up leaving about three-fourths to one inch of heel or ham wedge.

**6. Square-cut seedless bellies (Board of Trade trim)**—The fatback edge was trimmed to carry  $1\frac{1}{4}$  to  $1\frac{1}{2}$  inches of fatback outside the loin scribe. The shoulder end was merely straightened, with the full shoulder brisket left on the belly. The flank end was trimmed with a one-inch slant; that is, the belly side was left one inch longer than the fatback side.

The belly edge was cut differently for the two sexes. The belly edge on a barrow was trimmed only to remove the "pizzle mark" and to straighten the edge. The belly edge on a sow was trimmed sufficiently to remove all evi-

dence of "seed." To do this the first cut was made through the teat line, then it was belly-strapped by making one-eighth inch cuts until all seed was removed.

**7. Trimmings**—The trimmings were not weighed separately but their pooled yield was calculated by subtracting the total weight of the above-described cuts from the carcass weight. Therefore, the yield of trim as determined for this study included fat trim, lean trim, spareribs, neck bone, tail bone, and feet taken collectively and was probably subject to considerable error. It was undoubtedly influenced by the cutter's art in trimming and therefore is not reliably indicative of the degree of waste in the carcass. Because of the error involved, trimmings have been left out of the tables but were included in the correlation studies.

## Calculation of the Carcass Yields

The yield of each of the wholesale cuts described above was determined for each hog and expressed as a percentage of the cold carcass weight; that is, the weight of the carcass prepared as illustrated in figures 1, 2, and 3 and described on pages 8 and 10. The yield of the five primal cuts was the total of the percentages for regular-style hams (skin on), picnics, Boston butts, loins (blade in), and square-cut seedless bellies.

The yields of the fatbacks, plates, and jowls were calculated separately

in relation to the weight of the cold carcass. The leaf fat was handled in a similar way; that is, it was expressed as a ratio to the same cold carcass weight as the above fat cuts and the five primal cuts.

An index of fat cuts was calculated by adding the weights of the fatbacks, plates, leaf fat, and jowls together and dividing the total by the weight of the cold carcass with the leaf out. This figure was expressed as a percentage and was actually very little higher (ranging from 0.3 per cent to 0.4 per cent higher) than if the leaf fat had been included in the cold carcass weight. In any event, this index of fat cuts is quite satisfactory for comparative purposes and is an indication of fatness in the carcass as a whole.

It was impossible to slaughter all of the pigs at the same weight. Because of the variable distances between the stations and the packing plant, and because the pigs came from many different sources, it was always necessary to wait until at least a truckload was ready for market before running a slaughter test. Consequently, the weights varied both within and between truckloads.

The pigs used in this study ranged from 170 to 280 pounds live weight at the time of slaughter and averaged 216.5 pounds. In order to make the carcass yield data comparable between breed groups, corrections were made on the basis of difference in carcass weight, since high correlations were found between yield and weight.

## I. THE EFFECTS OF BREEDING ON CARCASS CHARACTERISTICS

### Literature

**L**USH (15) presented some evidence that selection on the basis of progeny tests used under the Danish system

had been effective in changing carcass characteristics in swine produced in Denmark over a period of years. These changes included (1) an increase in

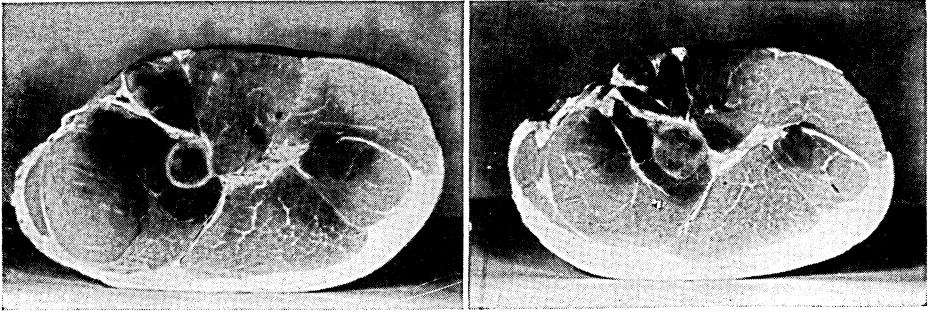


Fig. 4. Left, ham from an M-2-M crossbred; right, ham from a 2-2-1 crossbred. Both hams show small outer layer of fat, well-distributed fat within the lean, and small bone.

body length, (2) a decrease in thickness of backfat, (3) a slight increase in belly thickness, particularly in the Landrace breed, and (4) a very slight decrease in dressing percentage and yield of export bacon (based on live weight). For yield of export bacon he reported a heritability estimate of 0.20, for thickness of backfat 0.47, for thickness of belly 0.46, and for body length 0.54.

Blunn and Baker (3) in a study of Duroc Jersey swine reported the heritability of backfat thickness as 12.3 per cent, length of ham as 23.3 per cent, and circumference of ham as 16.6 per cent. Litter environment was responsible for 24.7 per cent of the variability in backfat thickness, for 18.0 per cent of the variability in length of ham, and for only 3.7 per cent of the variability in ham circumference. Environmental factors peculiar to the pigs within litters accounted for 63.0 per cent of the variability in backfat thickness, for 58.7 per cent of the variability in length of ham, and for 79.7 per cent of the variability in ham circumference.

Dickerson (9) reported heritability estimates of .52, .59, and .54 for three different factors associated with degree of fatness in swine carcasses from the Iowa swine breeding project. He also found heritability estimates of .29 for yield of lean cuts (based on the live weight of the hog), .73 for length of carcass, and .58 for length of hind leg.

Stohart (25) reported the heritability of carcass score as 35 per cent, of length of side as 42 per cent, and of backfat thickness as 37 per cent in Canadian bacon hogs.

In a study of the effect of plane of nutrition on the economy of production and carcass quality in swine, Winters *et al.* (30) observed that four groups of crossbred pigs from the Minnesota swine breeding project required only 78 per cent of the amount of total digestible nutrients needed for growth by a group of outbred pigs raised under similar conditions taken from the University of Minnesota purebred herds. The greater efficiency of the crossbred pigs over the purebred pigs was reflected in carcasses which had a higher content of lean cuts and a lower content of fat cuts.

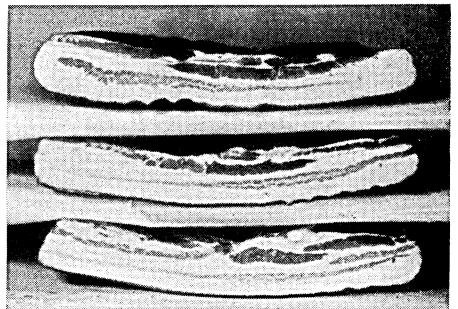


Fig. 5. Cured bacon cuts from an M-2-M crossbred. Note large amount of lean.

Table 1. Carcass Data by Breed Groups

	Selected market run—1	Selected market run—2	M	V	A	B	BS	C <sub>1</sub>	C <sub>2</sub>	C <sub>3</sub>	C	M-V
Number of carcasses .....	33	149	7	20	32	4	6	6	2	7	71	7
Live weight (pounds) .....	230.3	226.1	189.7	220.2	232.6	234.0	235.7	213.3	192.0	214.0	214.7	218.9
Dressing percentage .....	69.80	67.39	66.08	69.98	69.28	71.37	73.34	70.98	68.88	71.09	69.50	69.09
Cold carcass weight (pounds) .....	160.8	152.3	125.4	154.3	161.4	167.0	172.8	151.4	132.3	152.1	149.2	151.2
<b>Backfat thickness</b>												
Thinnest (inches) .....	1.47	1.30	1.11	1.26	1.18	1.25	1.52	1.31	1.32	1.29	1.08	1.30
Thickest (inches) .....	2.12	2.00	1.43	1.87	1.88	1.60	2.00	1.71	1.63	1.81	1.72	1.83
Seventh rib (inches) .....	1.84	1.57	1.29	1.44	1.50	1.51	1.77	1.59	1.32	1.52	1.36	1.50
Average (inches) .....	1.81	1.62	1.28	1.53	1.52	1.45	1.76	1.54	1.42	1.54	1.39	1.54
Length of carcass (inches) .....	30.2	29.5	28.9	29.9	30.2	31.1	30.7	29.5	30.0	29.4	29.6	29.9
<b>Five primal cuts*</b>												
Hams* .....	20.34	21.42	22.66	22.35	21.71	22.55	21.90	22.56	22.22	22.64	22.32	23.13
Picnics* .....	8.77	9.49	10.24	9.48	9.44	8.96	9.29	9.56	10.00	9.55	9.95	9.87
Boston butts* .....	6.77	7.57	7.12	7.00	6.71	6.56	6.67	7.01	7.47	6.76	6.69	6.96
Loins* .....	15.98	15.13	14.94	14.94	14.32	15.55	14.25	14.91	15.86	14.51	15.01	15.13
Bellies* .....	14.78	15.90	13.87	17.49	18.51	16.06	16.03	14.40	13.49	15.54	16.92	12.96
<b>Index of fat cuts*</b>												
Fatbacks* .....	9.95	8.73	8.48	8.11	8.06	8.41	10.00	9.60	12.10	8.80	8.25	9.54
Plates* .....	2.94	2.72	2.49	2.85	3.06	2.48	3.15	3.05	3.19	2.98	2.89	2.41
Leaf fat* .....	3.29	3.39	2.52	2.31	2.45	2.34	2.73	2.11	2.93	2.22	2.40	2.28
Jowls* .....	4.13	3.60	4.37	3.71	3.72	3.85	4.43	4.07	4.14	4.12	3.95	3.87
Loss in skinning hams* .....				1.75	1.80						1.89	

\* Per cent, based on the cold weight of the carcass dressed packer style.

Table 1. Carcass Data by Breed Groups—Continued

	C-M	V-BS-WL	Minn. No. 1	Minn. No. 2	1-V	1-V-1	V-1-V-1	1-M	1-1-M	M-1-1-M	C-1	2-M
Number of carcasses .....	1	5	30	4	22	5	7	23	8	7	22	7
Live weight (pounds) .....	205.0	206.0	209.6	215.0	220.9	197.6	222.9	220.5	204.8	224.4	209.6	220.9
Dressing percentage .....	68.29	72.23	69.21	71.28	68.92	67.86	68.37	68.95	67.92	68.65	68.83	68.81
Cold carcass weight (pounds) .....	140.0	148.8	145.2	153.3	152.3	134.1	152.5	152.1	139.1	154.1	144.4	152.1
<b>Backfat thickness</b>												
Thinnest (inches) .....	1.00	1.25	1.48	1.13	1.46	1.18	1.36	1.42	1.28	1.30	1.24	1.14
Thickest (inches) .....	1.40	1.75	1.92	1.50	1.87	1.64	1.90	1.97	1.66	1.81	1.76	1.67
Seventh rib (inches) .....	1.20	1.35	1.61	1.28	1.58	1.40	1.56	1.55	1.39	1.51	1.39	1.33
Average (inches) .....	1.20	1.45	1.67	1.30	1.67	1.41	1.60	1.65	1.44	1.54	1.47	1.38
Length of carcass (inches) .....	28.5	29.5	31.0	31.8	30.5	30.3	30.7	30.3	30.1	30.0	30.7	30.2
<b>Five primal cuts*</b>												
Hams* .....	70.40	71.14	70.71	71.06	68.71	71.22	70.99	67.82	71.05	70.46	71.74	71.19
Hams* .....	21.43	24.20	21.02	21.78	21.29	20.85	21.08	22.13	21.15	21.72	21.69	21.58
Picnics* .....	9.82	9.74	8.53	9.44	8.73	9.14	8.81	8.71	9.03	8.88	9.22	9.14
Boston butts* .....	7.50	6.70	6.75	7.25	6.64	7.24	6.99	6.62	7.00	6.80	7.03	7.07
Loins* .....	14.33	16.18	16.66	17.26	15.14	16.69	15.26	14.85	16.79	14.87	16.39	15.83
Bellies* .....	17.32	14.32	17.75	15.33	16.90	17.30	18.85	15.51	17.08	18.20	17.40	17.57
<b>Index of fat cuts*</b>												
Fatbacks* .....	15.27	15.24	18.59	16.11	19.33	18.28	17.60	20.27	17.88	18.42	17.65	16.04
Plates* .....	6.07	7.79	9.04	7.75	10.07	9.28	8.62	10.29	9.79	8.88	8.52	7.65
Leaf fat* .....	3.93	2.29	1.99	2.45	2.71	2.41	2.93	2.73	2.13	3.26	2.37	2.68
Jowls* .....	1.70	1.51	4.47	2.57	2.95	3.33	2.57	3.54	2.95	2.73	3.12	2.03
Jowls* .....	3.57	3.65	3.09	3.34	3.60	3.26	3.47	3.71	3.01	3.55	3.64	3.68
Loss in skinning hams* .....	1.61	.....	.....	.....	2.00	.....	1.83	.....	.....	1.87	1.74	1.68

\* Per cent, based on the cold weight of the carcass dressed packer style.

Table 1. Carcass Data by Breed Groups—Continued

	M-2-M	2-V	V-2-V	2-ML	2-BS	2-1	2-2-1	2-V-1	V-2-1	1-2-V-1	V-1-2-V-1	Schechter herd
Number of carcasses .....	24	6	6	2	1	21	4	1	4	2	2	34
Live weight (pounds) .....	210.4	200.0	220.7	213.0	254.0	209.4	213.3	216.0	209.4	206.0	212.5	200†
Dressing percentage .....	69.27	69.42	67.49	74.20	71.65	68.84	66.62	69.21	69.10	68.81	69.06	.....
Cold carcass weight (pounds) .....	145.7	138.8	149.1	158.3	182.0	144.3	142.0	149.5	145.0	141.8	146.8	137.2
<b>Backfat thickness</b>												
Thinnest (inches) .....	1.08	1.13	1.28	1.13	1.25	1.30	1.15	1.40	1.28	1.35	1.15	1.07
Thickest (inches) .....	1.79	1.57	1.73	1.57	1.75	1.81	1.95	1.70	2.05	1.65	1.65	1.74
Seventh rib (inches) .....	1.33	1.17	1.43	1.25	1.50	1.46	1.58	1.50	1.63	1.35	1.40	1.43
Average (inches) .....	1.40	1.29	1.48	1.32	1.50	1.53	1.56	1.53	1.65	1.45	1.40	1.41
Length of carcass (inches) .....	29.5	29.9	29.9	31.5	32.0	30.8	29.5	31.0	29.9	30.5	30.6	29.85
Five primal cuts* .....	71.72	71.76	71.10	70.04	70.88	70.06	72.17	69.65	72.23	70.29	72.38	71.41
Hams* .....	21.98	21.75	21.81	23.00	21.64	20.32	21.40	21.57	21.78	20.77	21.03	21.65
Picnics* .....	9.42	10.15	9.62	8.98	8.52	8.76	9.06	9.20	9.30	8.36	9.96	9.32
Boston butts* .....	7.11	6.93	6.94	7.20	6.29	6.86	6.89	6.39	6.98	5.75	7.04	7.41
Loins* .....	15.32	17.01	15.08	16.89	16.07	16.94	15.90	16.49	15.71	17.95	14.96	15.84
Bellies* .....	17.89	15.92	17.65	13.98	18.37	17.18	18.92	16.05	18.47	17.46	19.40	17.18
Index of fat cuts* .....	16.36	15.54	16.23	17.21	18.55	18.01	17.31	16.27	18.39	18.98	16.18	18.26
Fatbacks* .....	7.29	8.19	7.55	8.48	8.96	9.41	7.91	8.03	8.63	10.72	7.36	7.89
Plates* .....	3.05	2.31	3.01	2.73	2.78	2.49	3.13	2.13	3.30	1.87	2.68	2.59
Leaf fat* .....	2.13	1.56	1.97	2.12	2.41	2.84	2.63	2.43	2.38	3.04	2.38	2.96
Jowls* .....	3.88	3.48	3.70	3.89	4.40	3.27	3.63	3.68	4.08	3.35	3.76	4.82
Loss in skinning hams* .....	1.71	.....	1.59	.....	.....	1.65	1.66	.....	1.72	.....	1.78	1.59

\* Per cent, based on the cold weight of the carcass dressed packer style.

† Approximate.

Table 2. Carcass Data by Combined Breed Groups

	Selected market runs	Inbred PC lines	Minn. No. 1	Minn. No. 2	PC line crosses	Outbred PC	Outbred CW	Outbred DJ
Number of carcasses .....	182	155	30	4	13	15	32	45
Live weight (pounds) .....	226.9	216.2	209.6	215.0	210.0	221.6	210.2	227.2
Dressing percentage .....	67.83	70.06	69.21	71.28	69.87	71.31	71.39	70.41
Cold carcass weight (pounds) .....	153.84	151.8	145.2	153.3	146.7	157.9	150.0	160.0
<b>Backfat thickness</b>								
Thinnest (inches) .....	1.33	1.26	1.48	1.13	1.18	1.25	1.52	1.50
Thickest (inches) .....	2.02	1.74	1.92	1.50	1.66	1.91	2.17	2.35
Seventh rib (inches) .....	1.62	1.48	1.61	1.28	1.35	1.53	1.78	1.95
Average (inches) .....	1.65	1.49	1.67	1.30	1.40	1.57	1.82	1.93
Length of carcass (inches) .....	29.6	29.9	31.0	31.8	29.3	29.9	28.7	29.8
<b>Five primal cuts*</b>								
Hams* .....	68.99	69.55	70.71	71.06	69.86	69.99	67.72	68.66
Picnics* .....	21.22	22.32	21.02	21.78	22.92	22.04	20.86	20.62
Boston butts* .....	9.36	9.61	8.53	9.44	9.81	9.28	8.53	8.68
Loins* .....	7.42	6.89	6.75	7.25	7.05	6.78	6.87	6.27
Bellies* .....	15.28	14.92	16.66	17.26	15.21	15.11	14.08	13.82
	15.70	15.81	17.75	15.33	14.87	16.78	17.39	19.27
<b>Index of fat cuts*</b>								
Fatbacks* .....	18.79	18.48	18.59	16.11	16.20	19.29	22.25	21.66
Plates* .....	8.95	9.09	9.04	7.75	7.80	9.35	11.24	10.46
Leaf fat* .....	2.76	2.90	1.99	2.45	2.88	2.89	3.80	3.43
Jowls* .....	3.37	2.45	4.47	2.57	1.83	2.87	2.97	3.72
	3.70	4.04	3.09	3.34	3.70	4.19	4.24	4.04
Loss in skinning hams* .....		1.81			1.61	2.02	2.10	2.22

\* Per cent, based on cold weight of the carcass dressed packer style.

Table 2. Carcass Data by Combined Breed Groups—Continued

	1-V combina- tions	1-M combina- tions	C-1 combina- tions	2-M combina- tions	2-V combina- tions	1-2 combina- tions	1-2-V combina- tions	Schechter herd
Number of carcasses .....	34	38	22	31	12	25	8	34
Live weight (pounds) .....	213.8	216.6	209.6	215.7	210.4	211.4	209.4	200†
Dressing percentage .....	68.38	68.51	68.83	69.04	68.46	67.73	68.99	.....
Cold carcass weight (pounds) .....	146.3	148.4	144.4	148.9	144.0	143.2	144.5	137.2
<b>Backfat thickness</b>								
Thinnest (inches) .....	1.33	1.33	1.24	1.11	1.21	1.23	1.26	1.07
Thickest (inches) .....	1.80	1.81	1.76	1.73	1.65	1.88	1.78	1.74
Seventh rib (inches) .....	1.51	1.48	1.39	1.33	1.30	1.52	1.46	1.43
Average (inches) .....	1.56	1.54	1.47	1.39	1.39	1.55	1.50	1.41
Length of carcass (inches) .....	30.5	30.1	30.7	29.9	29.9	30.2	30.3	29.85
<b>Five primal cuts*</b>								
Hams* .....	70.31	69.78	71.74	71.46	71.43	71.12	71.63	71.41
Picnics* .....	21.07	21.67	21.69	21.78	21.78	20.86	21.19	21.65
Boston butts* .....	8.89	8.87	9.22	9.28	9.89	8.91	9.21	9.32
Loins* .....	6.96	6.81	7.03	7.09	6.94	6.88	6.59	7.41
Bellies* .....	15.70	15.50	16.39	15.58	16.05	16.42	16.21	15.84
.....	17.68	16.93	17.40	17.73	16.79	18.05	18.44	17.18
<b>Index of fat cuts*</b>								
Fatbacks* .....	18.40	18.86	17.65	16.20	15.89	17.66	17.85	18.26
Plates* .....	9.32	9.65	8.52	7.47	7.87	8.66	8.90	7.89
Leaf fat* .....	2.68	2.71	2.37	2.87	2.66	2.81	2.62	2.59
Jowls* .....	2.95	3.07	3.12	2.08	1.77	2.74	2.60	2.96
.....	3.44	3.42	3.64	3.78	3.59	3.45	3.73	4.82
Loss in skinning hams* .....	1.92	1.87	1.74	1.70	1.59	1.66	1.75	1.59

\* Per cent, based on cold weight of the carcass dressed packer style.

† Approximate.

Hammond and Murray (12) observed that first-cross pigs from two different pure breeds at similar weights produced carcasses in which the backfat and belly thickness were intermediate between the two parental breeds but the body length was slightly above the mean of the parental breeds.

Donald (10) in a study of two different groups of bacon pigs found hereditary differences in the relationship between growth rate and carcass characteristics, suggesting that it might be unwise to attempt to make detailed predictions of carcass quality on the basis of growth rate. He also observed hereditary differences in the relationship between backfat thickness and length of loin.

## Experimental

Carcass data by breed groups of hogs from the two selected market runs, from the Minnesota swine breeding project, and from the Schechter herd are given in table 1. Table 2 contains much the same data as table 1, but the breeds have been combined into fewer and larger groups and pigs from the University of Minnesota outbred herds that were full-fed during the entire time before slaughter are included. The breed group differences are highly significant in all characteristics.

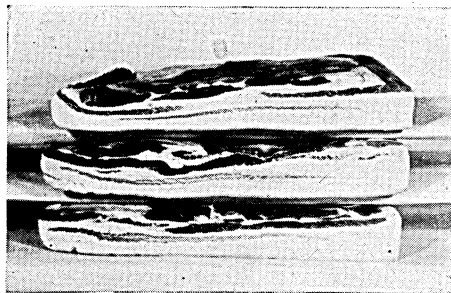


Fig. 6. Fresh bacon cuts from a C-1 crossbred. Note the uniformity in the distribution of lean.

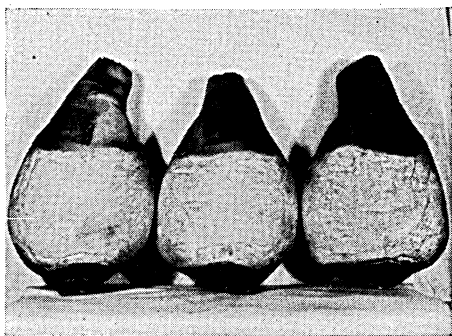


Fig. 7. Hams from three Minnesota line crosses. Note the fullness of muscle and the short shanks.

Table 3 shows the means for the various breed groups of the yield of five primal cuts, index of fat cuts, average backfat thickness, and length of carcass—all adjusted for differences in carcass weight. The differences among the groups for these four characteristics are still highly significant after adjustment to a common carcass weight of 150.21 pounds.

Hogs from three of the best-performing inbred lines of Poland Chinas (V, A, and C), the Minnesota No. 1 line, the Minnesota No. 2 line, the V-BS-WL line crosses, and all of the crosses between breeds produced carcasses which yielded a higher percentage of five primal cuts than those hogs from the selected market runs. In most instances the content of fat cuts was lower, the exception being in the Minnesota No. 1 line and crosses with it. This exception is principally due to the fact that the Minnesota No. 1 has a higher content of leaf fat than other pigs used in this experiment.

Hogs from the other inbred lines, particularly the M line, produced carcasses with a lower yield of five primal cuts and higher indexes of fat cuts. The outbred Poland China carcasses were higher in yield of five primal cuts but also slightly higher in fat cuts. The other two groups of outbred hogs were

Table 3. Mean Carcass Measurements and Yields by Breed Groups—Adjusted to a Common Carcass Weight of 150.21 Pounds or a Live Weight of about 217 Pounds

	No.	Yield of five primal cuts*	Index of fat cuts*	Average backfat thickness	Carcass length
		per cent	per cent	inches	inches
Selected market runs .....	182	69.16	18.58	1.62	29.5
A, V, and C .....	123	71.18	16.97	1.44	29.7
M .....	7	67.64	19.32	1.49	29.8
Other inbred Poland Chinas .....	25	69.09	19.05	1.50	30.0
M-V and M-C .....	8	69.01	16.95	1.41	29.4
V-BS-WL .....	5	71.07	15.32	1.46	29.6
Minn. No. 1 .....	30	70.47	18.88	1.71	31.2
Minn. No. 2 .....	4	71.21	15.93	1.27	31.7
Outbred PC .....	15	70.36	18.84	1.50	29.6
Outbred CW .....	32	67.71	22.26	1.82	28.7
Outbred DJ .....	45	69.13	21.08	1.85	29.4
Breed crosses					
1-V combinations .....	34	70.12	18.63	1.59	30.6
1-M combinations .....	38	69.69	18.96	1.56	30.2
C-1 combinations .....	22	71.46	17.99	1.52	30.9
2-V combinations .....	12	71.13	16.25	1.44	30.1
2-M combinations .....	31	71.40	16.27	1.40	29.9
2-1 .....	21	69.78	18.35	1.58	31.0
2-2-1 .....	4	71.78	17.79	1.63	29.8
1-2-V combinations .....	8	71.36	18.18	1.54	30.7
Schechter herd .....	34	70.79	19.02	1.52	30.4

\* Per cent, based on cold weight of the carcass dressed packer style.

lower in yield of five primal cuts than the market run and considerably higher in yield of fat cuts. The differences between these two outbred groups and the better inbred lines and crossbreds are even more pronounced.

Pigs from the Minnesota No. 1 line and from the Minnesota No. 2 line yielded the longest carcasses, and the Minnesota No. 1 crossbreds were decidedly longer than those of Poland China parental lines. The shortest carcasses came from the outbred Chester Whites.

Carcasses from the inbred Poland China lines, Poland China line crosses, and the Minnesota No. 2 line carried the least amount of backfat. The outbred Duroc Jersey and Chester White groups had the thickest backfat of all the groups tested.

The carcasses yielding the smallest amount of valuable cuts came from the M line of Poland Chinas and the outbred Chester Whites. The latter group had the fattest carcasses, followed very

closely by those from the outbred Duroc Jerseys. The Chester Whites and Duroc Jerseys had the most wasteful of any of the groups of carcasses cut during the course of these tests.

The following results were noted in the yield of the particular cuts:

1. Poland Chinas yielded the highest proportion of hams, and whenever the

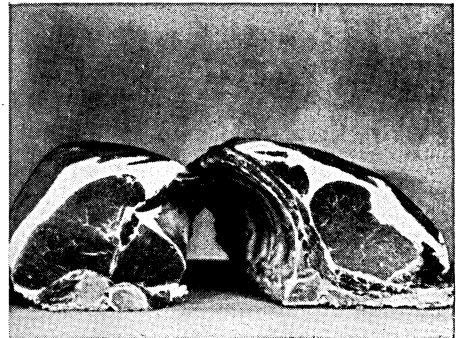


Fig. 8. Loin cuts from a 2-1 crossbred. Note the fullness of the kernel of lean.

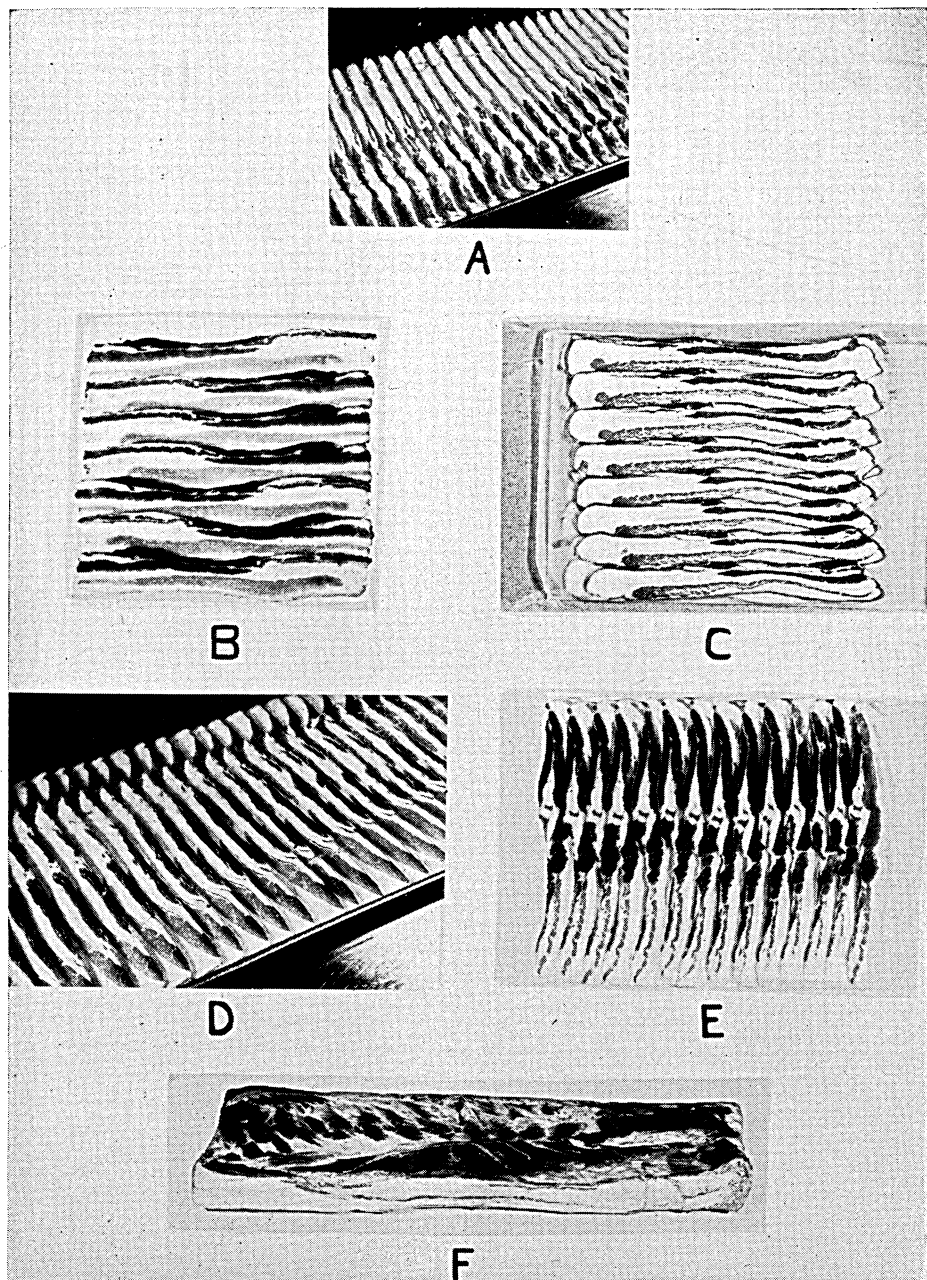


Fig. 9. Bacon from the following sources: A—the general market run; B—a Minnesota No. 1 hog; C—a Minnesota No. 2 hog; D—a 2-1 crossbred; E—a cross of Minnesota lines; F—a 2-1 crossbred (slab). Note the uniformity of thickness and the indications of leanness. Also note the high amount of lean, good distribution of lean, and low amount of fat in the bacon of the Minnesota No. 1 and No. 2 and their crosses, in comparison with bacon from the general market run.

Poland China lines were used in crossing, the ham yield was increased.

2. Although the yield of bellies was high in the outbred Duroc Jerseys, their bellies were of low grade because of an excessive amount of fat and a very noticeable lack of lean. The yield figure in this case is not adequate in appraising the true value of the carcass for bacon. However, the Minnesota No. 1 carcasses produced bacon which was of excellent quality (very well streaked with lean and with little fat) and higher in yield than that produced by any of the other groups. Whenever the Minnesota No. 1 line was used in a cross the belly yield was increased and the quality in most instances was improved. Minnesota No. 1 carcasses also showed a very high yield of loin (because of their increased length of body) and this quality was carried over into crosses between this line and the Poland China lines. Other characteristics of the Min-

nesota No. 1 line were fineness of bone, fullness of the "pocket" in the belly, and uniformity of the belly in both thickness and distribution of lean. These characteristics were also quite noticeable in the crosses between this line and others. The Minnesota No. 1 hogs have smaller and smoother shoulders than most other breeds and hence have a lower yield of clear plates and picnics.

3. The most outstanding features of carcasses from the Minnesota No. 2 line were high yield of loin, low index of fat cuts, marked fullness of the "kernel of lean" of the loin, and increased thickness of lean in the belly. Again these characteristics were carried over into the crossbreds in which the Minnesota No. 2 was used.

Various cuts of pork taken from individual carcasses used in the study are shown in figures 4 through 9. Many of the breed characteristics noted above are quite evident in these photographs.

## II. THE EFFECTS OF PLANE OF NUTRITION ON CARCASS CHARACTERISTICS

### Literature

**M**CMEEKAN (19) and McMeekan and Hammond (21 and 22) reported the effects of different planes of nutrition on carcass composition and form in pigs. In their experiments 80 pigs from a highly inbred line of Large White hogs were used. They were divided into four lots, and by controlled feeding each lot was made to follow a certain growth curve from birth until 200 pounds was reached.

Some of the pigs in the experiments of these workers were slaughtered at 16 weeks of age, and it was found that the early developing parts of the body from the low plane group had been retarded considerably in comparison to the high plane group. The pigs remain-

ing on feed were slaughtered at 200 pounds and the carcasses completely dissected. The groups were as follows:

Group	Method of feeding	Weight in pounds at 16 weeks	Age in days at 200 pounds
High-high	Full fed from birth until 200 pounds	100	165
High-low	Full fed from birth to 16 weeks, then feed restricted until 200 pounds	100	211
Low-high	Feed restricted from birth to 16 weeks, then full fed until 200 pounds	50	211
Low-low	Feed restricted from birth until 200 pounds	50	327

The high-low group produced what McMeekan and Hammond considered

Table 4. Feed Lot Data on Pigs Fed at Various Levels of Food Intake

	Lots			
	1	2	3	4
Feeding practice, first period .....	full-fed	full-fed	restricted	restricted
Feeding practice, second period .....	full-fed	restricted	full-fed	restricted
Average initial weight in pounds per pig .....	42.25	41.75	42.85	41.80
Average daily rate of gain, first period .....	1.22	1.21	.72	.72
Average daily rate of gain, second period .....	1.63	1.17	2.16	1.24
Average daily rate of gain, both periods .....	1.40	1.19	1.11	0.92
Average weight in pounds at close of experiment.....	217	214	215	216
Average age in days at completion of trial .....	206	219	230	266
Feed per 100 pounds gain, initial weight to 125 pounds	339	337	334	338
Feed per 100 pounds gain, 125 pounds to final weight	423	422	444	391
Feed per 100 pounds gain, entire period* .....	383	381	391	365

\* In order to adjust for the change from pasture to dry lot the pigs were charged the same amount of feed from pasture as alfalfa supplied in dry lot.

the best carcasses and good bacon type. Carcasses from this group had maximum muscular and skeletal development and little fat. The low-high group produced the poorest carcasses. These pigs represented a fatty, chuffy, lard type and the carcasses showed a stunted development of skeleton and muscle with a large amount of fat.

The high-high group was intermediate in these respects. The low-low group produced the least amount of fat, yet these pigs were undeveloped in all respects and showed a high proportion of bone. The groups did not overlap.

General conclusions made by McMeekan and Hammond were that rapid rate of growth early in life when frame and muscle are developing gives the type of pork carcass which is in greatest demand, one which has thick well-developed muscles and a small proportion of bone. These workers, however, do not say that feeding methods can overcome limits imposed by the breed but that breed characters can be modified by feeding. They do suggest that breed selection could be done best in the nutritional environment which develops the characters in the desired direction, for then only is the development limited by the breed alone.

Verges (26) conducted an experiment similar to those reported by McMeekan and Hammond, but used sheep. He found that lambs from the high-high group produced the best carcasses and showed proportionally less bone, while the other three groups lacked particularly in finish. The difference in results is due to different end points in each species; that is, lambs are slaughtered younger in development than pigs.

The important fact is that the experiments with both sheep and pigs showed that rapid rate of growth early in life is conducive to high carcass quality.

Table 5. TDN Supplied and TDN Available for Growth of Hogs Fed at Various Levels of Feed Intake

	Lots			
	1	2	3	4
Average TDN per pound of gain .....	3.13	3.14	3.18	2.98
TDN available over and above maintenance per pound of gain:				
First period .....	1.93	1.90	1.34	1.34
Second period .....	2.32	1.97	2.68	1.85
Both periods .....	2.13	1.94	2.05	1.61

Table 6. Carcass Data by Lot and Breed of Outbred Hogs in Self- and Restricted-Feeding Trial

	Poland China				Chester White			
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 1	Lot 2	Lot 3	Lot 4
Number of carcasses .....	4	5	6	6	7	7	8	8
Live weight (pounds) .....	214.8	219.2	219.8	226.8	206.4	208.6	215.4	214.6
Dressing percentage .....	71.40	70.15	68.40	68.89	70.46	68.85	68.29	68.55
Cold carcass weight (pounds) .....	153.3	153.9	150.3	156.3	145.3	143.6	147.1	147.2
<b>Backfat thickness</b>								
Thinnest (inches) .....	1.20	1.06	1.05	1.03	1.36	1.10	1.30	1.19
Thickest (inches) .....	1.83	1.72	1.68	1.65	2.10	1.67	1.86	1.63
Seventh rib (inches) .....	1.48	1.36	1.33	1.23	1.57	1.39	1.49	1.36
Average (inches) .....	1.50	1.38	1.36	1.31	1.67	1.39	1.55	1.39
Length of carcass (inches) .....	28.8	29.4	29.1	29.6	28.9	28.7	28.8	28.5
<b>Five primal cuts*</b>								
Hams* .....	70.29	71.39	70.06	72.25	68.76	70.46	70.15	72.26
Picnics* .....	22.56	22.66	22.61	23.13	21.26	22.80	22.57	22.96
Boston butts* .....	9.63	9.60	9.29	9.80	8.65	9.19	9.10	9.54
Loins* .....	6.55	7.02	6.95	7.15	7.09	7.36	7.03	7.66
Bellies* .....	14.92	15.24	15.23	16.52	14.52	15.17	15.11	16.22
Bellies* .....	16.64	16.87	15.97	15.66	17.24	15.94	16.34	15.89
<b>Index of fat cuts*</b>								
Fatbacks* .....	18.76	16.92	16.88	15.31	20.64	18.38	18.72	17.00
Plates* .....	9.25	7.68	8.00	7.16	10.18	8.63	9.39	8.25
Leaf fat* .....	3.00	2.83	2.94	2.31	3.51	3.14	3.11	2.72
Jowls* .....	2.73	2.75	2.31	2.43	2.91	3.28	2.81	2.93
Jowls* .....	3.78	3.67	3.64	3.41	4.04	3.34	3.41	3.11
Loss in skinning hams* .....	2.33	1.84	1.99	1.65	1.95	1.87	1.92	1.71

\* Per cent, based on cold weight of the carcass dressed packer style.

Table 6. Carcass Data by Lot and Breed of Outbred Hogs in Self- and Restricted-Feeding Trial—Continued

	Duroc Jersey				Total			
	Lot 1	Lot 2	Lot 3	Lot 4	Lot 1	Lot 2	Lot 3	Lot 4
Number of carcasses .....	5	5	6	6	16	17	20	20
Live weight (pounds) .....	226.0	215.6	210.8	207.8	215.7	214.5	215.3	216.4
Dressing percentage .....	70.28	68.40	67.28	66.61	70.71	69.13	67.99	68.02
Cold carcass weight (pounds) .....	158.9	147.5	142.2	138.5	152.5	148.3	146.5	147.3
<b>Backfat thickness</b>								
Thinnest (inches) .....	1.40	1.20	1.20	1.05	1.32	1.12	1.18	1.09
Thickest (inches) .....	2.38	1.86	2.05	1.70	2.10	1.75	1.86	1.66
Seventh rib (inches) .....	1.92	1.68	1.67	1.47	1.66	1.48	1.50	1.35
Average (inches) .....	1.90	1.58	1.64	1.41	1.69	1.45	1.52	1.37
Length of carcass (inches) .....	29.6	29.2	28.5	29.1	29.1	29.1	28.8	29.1
<b>Five primal cuts*</b>								
Hams* .....	69.25	69.44	69.07	71.83	69.47	70.43	69.76	72.11
Picnics* .....	21.08	21.43	21.57	23.03	21.63	22.30	22.25	23.04
Boston butts* .....	8.86	8.84	9.17	9.50	9.05	9.21	9.19	9.61
Loins* .....	6.41	6.26	6.88	7.18	6.68	6.88	6.95	7.33
Bellies* .....	14.49	15.38	14.40	15.91	14.64	15.26	14.91	16.22
Fatbacks* .....	18.51	17.52	17.05	16.20	17.46	16.78	16.45	15.92
<b>Index of fat cuts*</b>								
Fatbacks* .....	21.29	19.77	18.95	16.62	20.23	18.36	18.18	16.31
Plates* .....	9.90	9.53	8.76	7.57	9.78	8.61	8.72	7.66
Leaf fat* .....	3.55	2.90	3.30	2.52	3.35	2.96	3.12	2.52
Jowls* .....	3.91	4.03	3.58	3.38	3.18	3.35	2.90	2.91
Loss in skinning hams* .....	3.93	3.30	3.31	3.14	3.92	3.44	3.45	3.22
Loss in skinning hams* .....	2.16	1.91	2.02	1.59	2.15	1.87	1.98	1.65

\* Per cent, based on cold weight of the carcass dressed packer style.

Table 7. Means of Carcass Yields and Measurements Adjusted for Differences in Carcass Weight of the Outbred Hogs in Self- and Restricted-Feeding Trial

Breed and lot	Number	Adjusted means of yield of five primal cuts	Adjusted means of index of fat cuts	Adjusted means of average back- fat thickness	Adjusted means of carcass length
		per cent*	per cent*	inches	inches
PC-1 .....	4	70.44	18.58	1.47	28.7
PC-2 .....	5	71.57	16.70	1.35	29.3
PC-3 .....	6	70.06	16.87	1.36	29.1
PC-4 .....	6	72.54	14.95	1.26	29.4
CW-1 .....	7	68.52	20.93	1.71	29.1
CW-2 .....	7	70.14	18.77	1.44	28.9
CW-3 .....	8	70.00	18.90	1.57	28.9
CW-4 .....	8	72.12	17.17	1.41	28.6
DJ-1 .....	5	69.77	20.78	1.83	29.3
DJ-2 .....	5	69.31	19.93	1.60	29.3
DJ-3 .....	6	68.69	19.42	1.71	28.8
DJ-4 .....	6	71.27	17.31	1.51	29.5
Lot 1 .....	16	69.58	20.09	1.67	29.0
Lot 2 .....	17	70.34	18.47	1.46	29.2
Lot 3 .....	20	69.58	18.40	1.55	28.9
Lot 4 .....	20	71.97	16.48	1.39	29.2

\* Per cent, based on cold weight of the carcass dressed packer style.

Mansfield and Trehane (16) fed one group of pigs on a full diet and another group on a restricted diet. They reported that the pigs on a restricted feed intake consumed less feed per unit of gain and yielded a higher percentage of carcasses in the high grades. Shorrock (23) reported that restriction in feeding after 100 pounds live weight had little effect on carcass quality in swine, except for a tendency toward the production of slightly thinner and softer backfat. Of course, Shorrock's restrictions were not as severe as those imposed by McMeekan and Hammond.

## Experimental

The feed lot data on the pigs taken from the University of Minnesota outbred herds and used in the self- and restricted-feeding trial (described on page 8) are given in table 4. Growth rate data on the same group of pigs by breed and lot are presented in table 14, but in the latter table they have been calculated from a weight and age reached prior to the start of the trial (at weaning age, 56 days). The average

ages of these pigs at the beginning of the experiment were as follows:

Poland Chinas—73.2 days	Lot 1—86.2 days
Chester Whites—79.3 days	Lot 2—78.3 days
	Lot 3—76.7 days
Duroc Jerseys—84.0 days	Lot 4—76.0 days

Up to this time, however, all had been treated alike, kept under the same conditions as the other outbred groups studied, and full fed. In any event the growth rates up to slaughter were in keeping with the methods of treatment.

The total feed per 100 pounds gain was highest for Lot 3 and lowest for Lot 4. But after allowances were made for maintenance, as given by Brody (4), and after the feed intake was converted to TDN, it was found that Lot 1 required more TDN above maintenance per unit of gain and Lot 4 required the least. Lots 2 and 3 were intermediate in this respect. The results of these calculations are presented in table 5, which appears on page 24.

The carcass data by breed and lot are given in tables 6 and 7. Those in table 7 have been adjusted for differences in carcass weight in order to make the

groups comparable. Lots 1 and 3 produced carcasses with the same yield of five primal cuts and both were lower than Lots 2 and 4. The carcasses from Lot 4 had the highest yield of five primal cuts but were criticized as soft and underfinished. Lot 1 yielded the fattest carcasses, Lot 4 the thinnest ones, and Lots 2 and 3 the intermediate ones in this respect. The differences in length of carcass between the lots were very slight, with Lot 3 producing the shortest.

The differences among the three breeds in regard to the degree of fatness of the carcass and yield of five primal cuts are in keeping with the results reported above for other groups of the same breeding. The data in tables 6 and 7 indicate that the three breeds do not necessarily follow the same order

with different treatments of feeding, however. Analyses of variance using expected subclass numbers according to the method outlined by Snedecor and Cox (24) were used to test the validity of this observation. In yield of five primal cuts the differences among lots were highly significant, yet the breed differences were not significant. Breed differences were greatest in Lots 1 and 2; the three breeds in Lot 4 showed a tendency for a high degree of similarity; but the interaction between breeds and lots was not significant. In regard to fatness of the carcasses, both breed and lot differences were highly significant with no significant interaction between lots and breeds. The main reason for the breed difference here lies in the fact that Poland Chinas yielded carcasses with consistently less

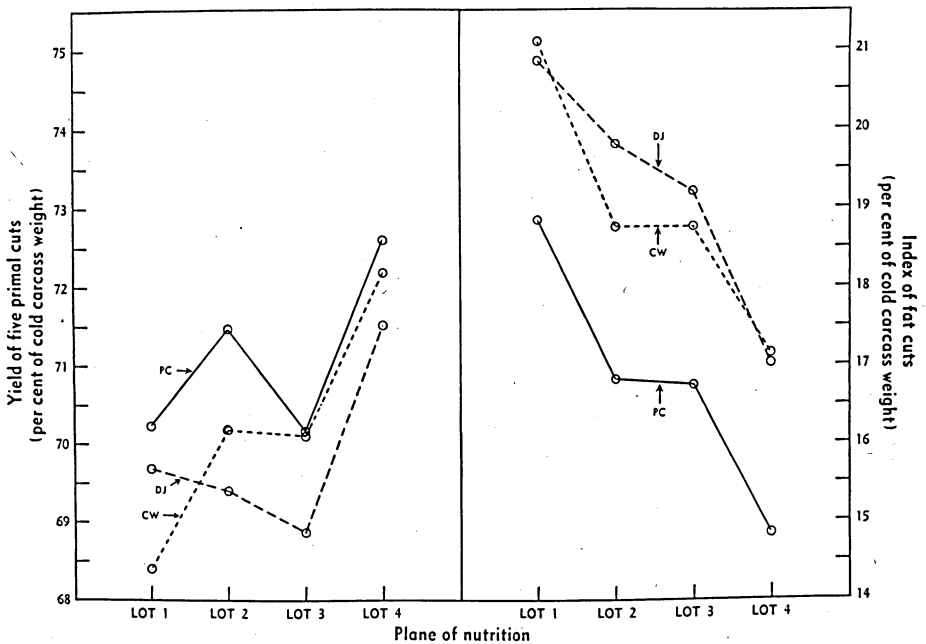


Fig. 10. Left, yield of the five primal cuts of the three breeds in relation to plane of nutrition. Right, index of fat cuts of the three breeds in relation to plane of nutrition. The yield of five primal cuts and the index of fat cuts have been corrected for differences in slaughter weight.

fat than either of the other two breeds. The Duroc Jerseys and the Chester Whites followed somewhat similar patterns of response to the feeding.

Figure 10 shows the above results in graphic form. The yields of the five

primal cuts and the indexes of fat cuts have been adjusted for differences in live weight at the time of slaughter. The same pattern was found when adjustments were made on the basis of cold carcass weight.

### III. RELATIONSHIPS BETWEEN CARCASS MEASUREMENTS AND YIELDS

#### Literature

**M**cmEEKAN (18 and 19) found that external measurements of the carcass did not provide reliable indications of quality of bacon pigs. Therefore, he suggests that concentration on internal measurements is desirable if further improvement in prediction is desired.

He found that length of foreleg or length of hind leg was highly correlated with the total amount of bone in the carcass, yet the combined weight of the cannon bones provided a better index of total skeletal weight than any linear measurement. He also found that the total weight of bone, muscle, and fat in the bacon pig carcass could be estimated with a high degree of accuracy from the weights of these tissues in either the loin or the leg. The combination of the composition of these two "joints" provided even higher correlations than either the loin or leg taken alone.

McMeekan further found that a combination of the length and depth measurements of the "eye" muscle provided a reliable basis for estimating the amount of muscle in the carcass. Total fat in the carcass was highly correlated with the average of five backfat measurements, and average backfat thickness over the rump was more highly correlated with total fat content than any measurements of fat taken at different regions.

In a study of the variations of muscle, fat, and bone of 30 swine carcasses, Aunan and Winters (1) found significant correlations between average backfat thickness and the following carcass characteristics:

- a. Dressing percentage,  $r = +0.66$
- b. Yield of the five primal cuts, expressed as a percentage of the cold carcass weight,  $r = -0.58$
- c. Total lean meat in the whole carcass,  $r = -0.63$
- d. Total fat content of the whole carcass,  $r = +0.79$
- e. Fat content of the ham,  $r = +0.66$
- f. Fat content of the picnic,  $r = +0.53$

They found no association between dressing percentage and the yield of five primal cuts, but the latter character was positively correlated with the lean content of the carcass ( $r = +0.50$ ). The total lean component was also positively correlated with area of the "kernel of lean" in the loin and with the content of lean in the loin, and the latter in turn was correlated with the percentage of lean in other primal cuts.

The total bone content of the primal cuts showed high positive correlations with the bone content of the ham and with the total of lean in the carcass. However, they found no association between carcass length and total yield of lean meat nor between the ham index (circumference of ham  $\times$  100, divided by length of ham) and the percentage of lean of the ham. There was also no correlation between uniformity of backfat thickness and yield of the five primal cuts.

Crampton (7) reported no relationship between length of side and degree of leanness of the carcass in Canadian hogs, yet Bennett and Coles (2) reported a negative correlation between length of side and thickness of shoulder fat in the same kind of hogs.

Hammond and Murray (12) found that the live weight of the pig affected carcass percentage (dressing percentage) more than breed or type, and they suggested an optimum carcass percentage of 79 per cent and an optimum yield of bacon of 58 per cent in bacon-type hogs. Their reasons were that if the percentages are above these figures, the carcasses will not be desirable because of too high a content of fat. And if they are below, the proportion of bone will be too high.

They found that the proportional increase of bacon weight is greater than the proportional increase in length of side. They also found that the belly thickness and thickness of shoulder fat increased at a faster rate than side

length but not as fast as weight of side. The thickness of fat over the loin increases faster with the increase in total carcass weight than does the weight of the side.

They found, too, that as the length of side increases (weight held constant), the thickness of the backfat decreases, yet there is no similar effect on belly thickness. As reported in the same work these authors found that the subcutaneous layer of fat matures earliest at the shoulder, over the rump next, and on the loin last, and that the rate of increase of backfat slows down as the sides increase in weight. This slackening of growth was greatest in the shoulder and least in the loin; the rump area was intermediate.

The ratio of the backfat thickness at the shoulder to the backfat thickness at the loin decreases soonest in the early-maturing breeds. Because the region of the last rib is the latest maturing part of the body, Hammond and Murray suggested that it should

Table 8. Relationships Between Weight of Carcass and Carcass Yields

Factors*	Total		Within breed groups	
	Correlation coefficient	Regression coefficient	Correlation coefficient	Regression coefficient
F/A	-.38†	-.0513†	-.40†	-.0480†
F/A.B	-.05	.....	-.08‡	.....
F/A.C	-.51†	.....	-.56†	.....
F/A.BC	-.20†	.....	-.27†	.....
L/A	+.36†	+.0584†	+.42†	+.0588†
L/A.B	+.08‡	.....	+.04	.....
L/A.C	+.46†	.....	+.57†	.....
L/A.BC	+.04	.....	+.22†	.....
Q/A	-.07	-.0071	-.11†	-.0108†
Q/A.B	+.14†	.....	+.04	.....
Q/A.C	-.07	.....	-.13†	.....
Q/A.BC	+.15†	.....	+.04	.....

\* Factors:

F = yield of five primal cuts (per cent).  
 L = index of fat cuts (per cent).  
 Q = yield of total trimmings (per cent).  
 A = cold carcass weight (pounds).  
 B = average backfat thickness (inches).  
 C = length of carcass (inches).

† Significant at one per cent level.

‡ Significant at five per cent level.

Table 9. Relationships Between Average Backfat Thickness and Carcass Yield\*

Factors†	Total		Within breed groups	
	Correlation coefficient	Regression coefficient	Correlation coefficient	Regression coefficient
F/B	-.65	-5.22	-.61	-4.96
F/B.A	-.57	.....	-.50	.....
F/B.C	-.66	.....	-.62	.....
F/B.AC	-.53	.....	-.41	.....
L/B	+.75	+7.31	+.69	+6.65
L/B.A	+.71	.....	+.61	.....
L/B.C	+.76	.....	+.71	.....
L/B.AC	+.68	.....	+.54	.....
Q/B	-.32	-2.10	-.25	-1.69
Q/B.A	-.34	.....	-.23	.....
Q/B.C	-.32	.....	-.25	.....
Q/B.AC	-.35	.....	-.22	.....

\* All correlations and regressions are significant at the one per cent level.

† Factors:

- F = yield of five primal cuts (per cent).
- L = index of fat cuts (per cent).
- Q = yield of total trimmings (per cent).
- A = cold carcass weight (pounds).
- B = average backfat thickness (inches).
- C = length of carcass (inches).

be at this place that the carcass should be cut in order to obtain a proper estimate of its development.

Lush (15) reported some correlations between carcass characteristics as determined by Jespersen *et al.* (14) on Danish swine, as follows:

Characteristic	Thickness of backfat	Thickness of belly	Dressing percentage
Body length	-.197	+.070	-.011
	-.145	+.053	-.019
Thickness of backfat		+.180	+.382
		+.218	+.308
Thickness of belly			+.383
			+.336

The upper figure is the correlation for 3,577 barrows; the lower figure is for 3,382 sows.

Lush (15) warns that since the data for many of the correlations were collected over a period of years, time changes resulting in differences in carcass characteristics may be responsible for the degree of association in many instances. From data on similar hogs Lush (15) found relatively low correlations between the yield of export bacon and thickness of backfat, thick-

ness of belly, and body length ( $r =$  approximately  $+.20$ ,  $+.30$ , and  $-.10$ , in the same order).

Warner *et al.* (27) found a very high correlation between the percentage yield of fat cuts (belly, leaf fat, skinned backfat, and fat trimmings) and the fat content of the edible meat, as determined by ether extraction ( $r = +0.91 \pm 0.01$ ). These authors suggested that the use of the percentage yield of fat cuts might be offered as a fat index of the entire carcass, but from observations reported later, it is doubtful that the belly should be included in the index because of its great variation in ratio of lean to fat.

Hankins and Ellis (13) found that average backfat thickness was highly indicative of the fat content (ether extract) of the edible pork cuts ( $r = +0.84 \pm 0.04$ ). They also stated that the single measurement of backfat thickness at the seventh rib also gave a very high correlation with the same character ( $r = +0.77 \pm 0.05$ ).

Table 10. Relationships Between Length of Carcass and Carcass Yields

Factors*	Total		Within breed groups	
	Correlation coefficient	Regression coefficient	Correlation coefficient	Regression coefficient
F/C	+ .13†	+ .245†	+ .11†	+ .202†
F/C.A	+ .38†	.....	+ .45†	.....
F/C.B	+ .22†	.....	+ .19†	.....
F/C.AB	+ .28†	.....	+ .32†	.....
L/C	-.11†	-.239†	-.10‡	-.201‡
L/C.A	-.33†	.....	-.44†	.....
L/C.B	-.22†	.....	-.20†	.....
L/C.AB	-.21†	.....	-.29†	.....
Q/C	.00	-.007	.00	-.001
Q/C.A	+ .03	.....	+ .07	.....
Q/C.B	+ .01	.....	+ .02	.....
Q/C.AB	-.07	.....	-.01	.....

## \* Factors:

F = yield of five primal cuts (per cent).

L = index of fat cuts (per cent).

Q = yield of total trimmings (per cent).

A = cold carcass weight (pounds).

B = average backfat thickness (inches).

C = length of carcass (inches).

† Significant at one per cent level.

‡ Significant at five per cent level.

Table 11. Relationships Between T Factor and Carcass Yields and Between U Factor and Carcass Yields\*

Factors†	Total		Within breed groups	
	Correlation coefficient	Regression coefficient	Correlation coefficient	Regression coefficient
F/T	-.67	-156.54	-.62	-149.07
F/T.A	-.61	.....	-.55	.....
F/U	+ .45	+ 2.19	+ .38	+ 1.97
F/U.A	+ .48	.....	+ .41	.....
L/T	+ .76	+ 216.60	+ .71	+ 198.12
L/T.A	+ .72	.....	+ .65	.....
L/U	-.60	-3.51	-.49	-2.95
L/U.A	-.64	.....	-.53	.....
Q/T	-.32	-60.19	-.25	-49.14
Q/T.A	-.32	.....	-.23	.....
Q/U	+ .34	+ 1.32	+ .23	+ .97
Q/U.A	+ .34	.....	+ .23	.....

\* All correlations and regressions are significant at the one per cent level.

## † Factors:

F = yield of five primal cuts (per cent).

L = index of fat cuts (per cent).

Q = yield of total trimmings (per cent).

A = cold carcass weight (pounds).

T = ratio of backfat thickness to carcass length.

U = weight per unit length of carcass ÷ average backfat thickness.

## Experimental

As mentioned before, individual carcass measurements, along with the yield of the various cuts, were obtained on 708 hogs from five sources. The relationships between the measurements taken and yield of five primal cuts, degree of fatness of the carcass and yield of total trimmings are given in tables 8-13. The degree of association has been measured by calculating simple and partial correlation coefficients along with the simple regression coefficients. This was done first by using data from all of the hogs without regard to breed differences (total) and then by correcting for breed differences, using variances and covariances within breed groups.

In addition to the simple measurements taken, the following factors were calculated and correlated with yield.

The following symbols have been used in the tables to designate these factors.

**S**—uniformity of backfat thickness.

This factor was calculated by taking the difference between the thickest and thinnest backfat measurements and dividing by the average backfat thickness.

**T**—ratio of average backfat thickness to carcass length, called the "T" factor. It was determined by merely dividing the average backfat thickness by the length of carcass.

**U**—the "U" factor. It was calculated by taking the ratio of the carcass weight to carcass length and dividing by the average backfat thickness.

The correlations and regressions between carcass yields and carcass weights are given in table 8. On the average within all breed groups, the

Table 12. Relationships Between Loss in Skinning Hams and Carcass Measurements and Between Loss in Skinning Hams and Carcass Yields

Factors*	Total		Within breed groups	
	Correlation coefficient	Regression coefficient	Correlation coefficient	Regression coefficient
V/B	+ .47†	+ .62†	+ .18†	+ 0.25†
V/B.A	+ .33†	.....	+ .09	.....
V/T	+ .50†	+ 19.11†	+ .22†	+ 8.78†
V/T.A	+ .40†	.....	+ .15†	.....
F/V	-.03	-.18	-.26†	-1.47†
F/V.A	+ .16†	.....	-.21†	.....
L/V	+ .54†	+ 3.97†	+ .26†	+ 1.68†
L/V.A	+ .46†	.....	+ .20†	.....
Q/V	-.09	-.42	-.05	-0.21
Q/V.A	-.05	.....	+ .03	.....

\* Factors:

F = yield of five primal cuts (per cent).

L = index of fat cuts (per cent).

Q = yield of total trimmings (per cent).

V = loss in skinning hams (per cent).

A = cold carcass weight (pounds).

B = average backfat thickness (inches).

T = ratio of backfat thickness to length of carcass.

† Significant at one per cent level.

Table 13. Relationships Between Uniformity of Backfat Thickness and Carcass Measurements and Between Uniformity of Backfat Thickness and Carcass Yields

Factors*	Total		Within breed groups	
	Correlation coefficient	Regression coefficient	Correlation coefficient	Regression coefficient
S/B	-.19†	-.1127†	-.21†	-.1366†
S/B.A	-.14†	.....	-.12†	.....
S/C	-.06	-.0081	+.09‡	+.0126‡
S/C.A	+.01	.....	+.25†	.....
S/C.B	-.05	.....	+.10‡	.....
S/C.AB	-.03	.....	+.22†	.....
F/S	+.25†	+3.43†	+.25†	+3.16†
F/S.A	+.22†	.....	+.19†	.....
F/S.B	+.17†	.....	+.16†	.....
F/S.AB	+.17†	.....	+.16†	.....
L/S	-.19†	-3.12†	-.19†	-2.75†
L/S.A	-.15†	.....	-.12†	.....
L/S.B	-.07	.....	-.06	.....
L/S.AB	-.07	.....	-.06	.....
Q/S	-.03	-0.32	-.04	-.42
Q/S.A	-.04	.....	-.06	.....
Q/S.B	-.10‡	.....	-.10‡	.....
Q/S.AB	-.09‡	.....	-.09‡	.....

## \* Factors:

F = yield of five primal cuts (per cent).  
 L = index of fat cuts (per cent).  
 Q = yield of total trimmings (per cent).  
 S = uniformity of backfat thickness.

A = cold carcass weight (pounds).  
 B = average backfat thickness (inches).  
 C = length of carcass (inches).

† Significant at one per cent level.

‡ Significant at five per cent level.

proportion of yield of five primal cuts decreased with an increase in cold carcass weight, and this decrease amounted to 0.05 per cent for each pound increase in weight. On the other hand, the index of fat cuts increased as the carcass weight increased, with this increase amounting to 0.06 per cent for each additional pound.

When the backfat thickness was held constant, the degree of relationship between these characteristics was reduced to mere significance in the former case and to nonsignificance in the latter. When corrections were made on the basis of carcass length only, the partial correlations were higher than the simple correlations and in the same direction. But when corrections for both backfat thickness and length were

made, practically no degree of association was left. This means merely that the heavier hogs were the fatter ones and hence their carcasses yielded a lower percentage of five primal cuts.

All of the correlations and regressions between carcass weight and yield of total trimmings were quite low, indicating no associations between these characters that could be used for any practical purpose.

The similarity between the total correlations and regressions and those from within breed groups is quite striking, indicating a high degree of homogeneity among the different groups in respect to association between carcass weight and yield. The same general situation holds true, as will be shown later, for the other carcass measurements in rela-

tion to yields of the three groups of carcass cuts.

The relationships between the average backfat thickness and carcass yields are presented in table 9. Backfat thickness apparently has a high value for predicting the yield of five primal cuts and total fat cuts. It has accounted for about 40 per cent ( $r^2$ ) of the variance in the five primal cuts and approximately 50 per cent ( $r^2$ ) of the variance in the fat cuts.

As the average backfat thickness increased, the yield of five primal cuts was reduced (five per cent for each inch increase in backfat), even when carcass weight, length of carcass, or both were held constant.

The index of fat cuts increased markedly with an increase in backfat thickness (seven per cent for each additional inch of backfat). As with the five primal cuts the relationship between backfat thickness and index of fat cuts remained consistently high when corrections were made for weight and length of carcass.

Figure 11 is a scatter diagram showing the relationship between backfat thickness and yield of the five primal cuts, using data from all of the 708 pigs in this experiment. The regression line for the yield of five primal cuts on average backfat thickness is also shown. There were no indications of nonlinearity in the regression, and no

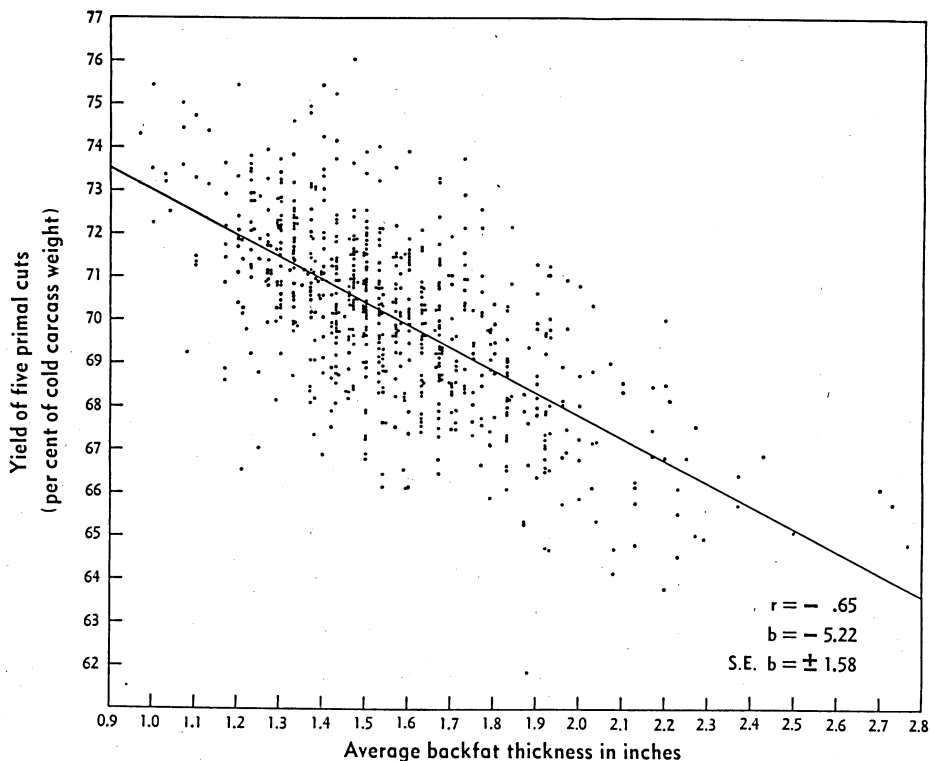


Fig. 11. Scatter diagram and regression line of yield of five primal cuts on average backfat thickness (708 hogs).

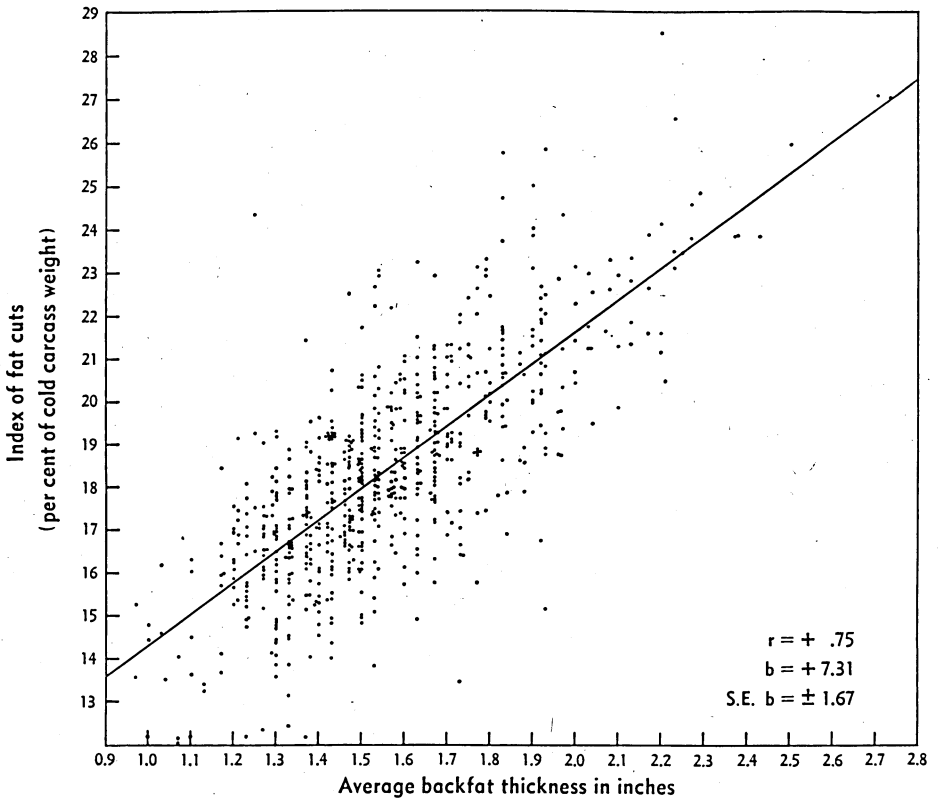


Fig. 12. Scatter diagram and regression line of index of fat cuts on average backfat thickness (708 hogs).

adjustments were made for carcass weight or length.

Figure 12, a scatter diagram which includes all 708 pigs, shows the relationship between the index of fat cuts and average backfat thickness. It also shows the regression line of index of fat cuts on backfat thickness. This regression line was rectilinear; no adjustments were made for carcass weight or length.

The correlations and regressions between average backfat thickness and yield of total trimmings were much lower than those dealt with in figures 11 and 12, though all were highly significant. These correlations and regres-

sions indicate that the fatter carcasses yielded proportionally less trimmings.

Length of carcass by itself had less association with the yield of five primal cuts, fat cuts, and total trimmings than did backfat thickness (table 10). The correlations between length and total trimmings were nonsignificant, but those between length and the other two yield factors were for the most part highly significant. When adjustments were made for carcass weight and backfat thickness, the degree of relationship was increased between length and yield of five primal cuts and between length and index of fat cuts. Within breed groups an increase of one

inch in the length of the carcass increased the yield of five primal cuts by 0.20 per cent and decreased the index of fat cuts by the same amount.

The T factor and the U factor, described above, have been correlated with the yield of five primal cuts, index of fat cuts, and yield of total trimmings. The results are reported in table 11. The T factor showed a higher degree of relationship to both yield of five primal cuts and index of fat cuts than did average backfat thickness

alone. Because the T factor (expressed as a decimal) was such a low figure in all cases, the regression coefficients appear to be very high.

The correlations between T and yield of five primal cuts are negative, for, as shown above, a decrease in backfat thickness and an increase in carcass length each accompanied an increase in the five primal cuts and a decrease in the index of fat cuts. Accordingly, a decrease in backfat thickness occurring with an increase in length of car-

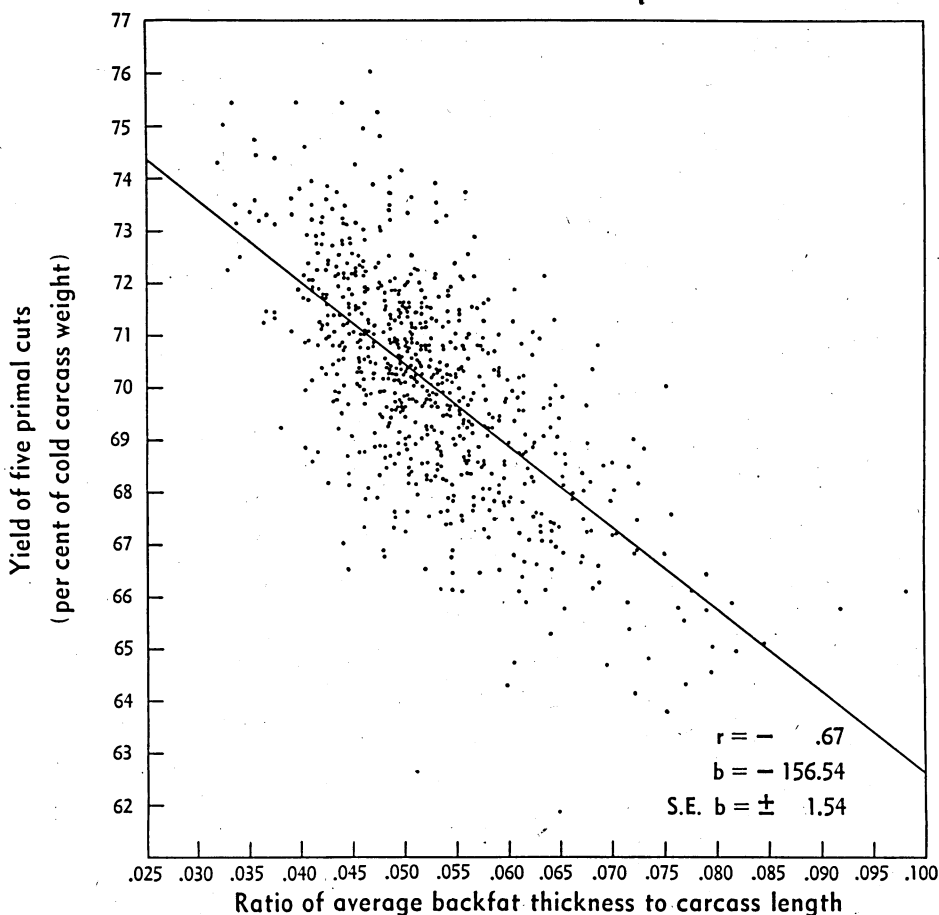


Fig. 13. Scatter diagram and regression line of yield of five primal cuts on T factor (708 hogs).

ness is reflected in a lower ratio between the two (the T factor).

Figures 13 and 14 are scatter diagrams showing the relationships between the T factor and yield of the five primal cuts and between T and index of fat cuts. Again the regression lines are rectilinear.

Correlations between the T factor and yield of the total trimmings were highly significant but considerably

lower than correlations between T and yield of the five primal cuts or index of fat cuts.

The U factor showed significant correlations with yield of the five primal cuts, index of fat cuts, and yield of total trimmings. However, the degrees of association were lower than those involving either backfat thickness or the T factor, except for correlations with total trimmings. There, all three

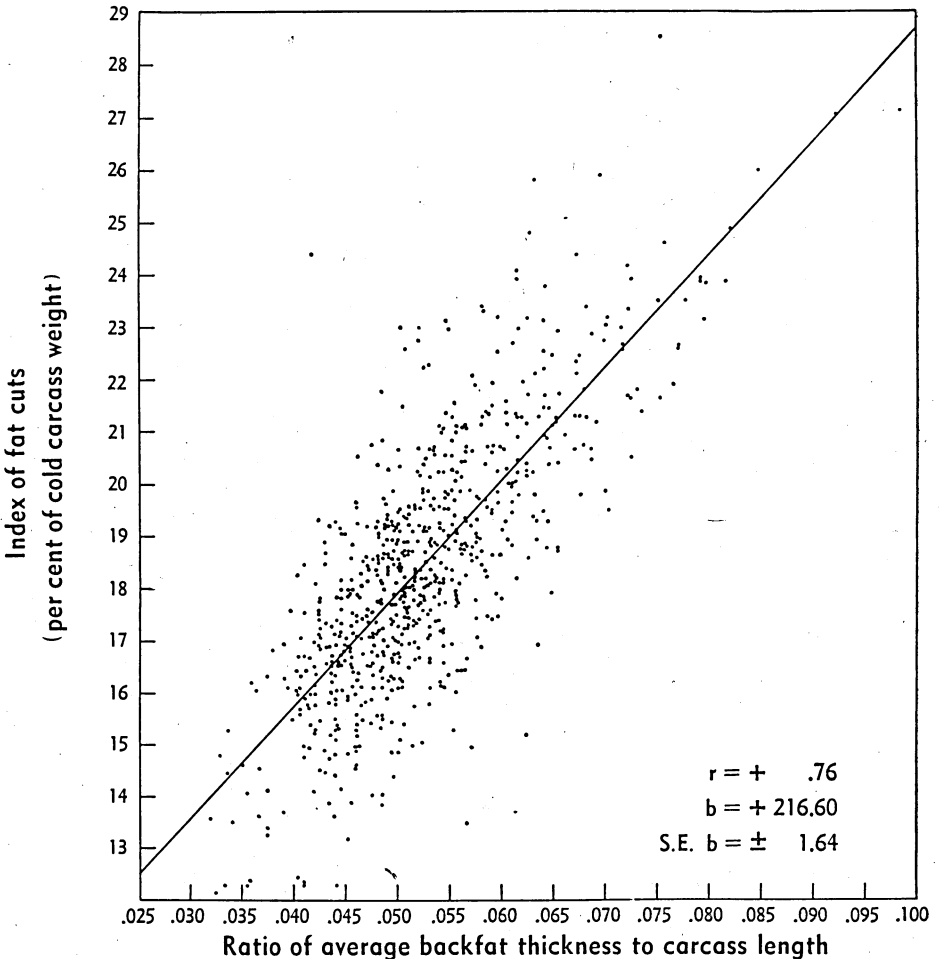


Fig. 14. Scatter diagram and regression line of index of fat cuts on T factor (708 hogs).

measurement factors showed about the same degree of association.

Table 12 presents correlations and regressions between the loss in skinning hams and carcass measurements and between loss in skinning the hams and carcass yields. Data on skinning hams were collected on only a part of the pigs tested (349 pigs) and did not represent all of the breed groups (see tables 1, 2, and 6).

Average backfat thickness was significantly and positively correlated with loss in skinning hams except when corrections were made for differences among breed groups and for carcass weight. The T factor showed positive and highly significant correlations with loss in skinning hams. An increase in the loss from skinning hams was associated with a decrease in the yield of five primal cuts and with an increase in the index of fat cuts.

The reason for the differences between the total correlations and the ones from within breed groups is that most of the carcasses, from which these data were collected, were from breed groups yielding fat carcasses. No significant association was found between loss in skinning the hams and yield of the total trimmings.

Uniformity of backfat thickness was studied in relation to the average thickness of backfat itself, to carcass length, and to carcass yields. These correlations are reported in table 13. It should be mentioned here that the lower the

value of the factor used to measure backfat uniformity, the greater the uniformity.

All of the correlations reported in table 13 are low even though most of them are highly significant. The fattest pigs showed the greatest amount of uniformity in the depth of backfat—a fact which was responsible for the positive correlation between this characteristic and yield of five primal cuts.

When corrections were made for average backfat thickness and carcass weight, there was no significant relationship between backfat uniformity and index of fat cuts. The same characteristic had practically no effect on yield of total trimmings. The longer pigs showed a tendency toward lack of uniformity in their backfat thickness, yet carcass length has accounted for only a very small part of the variation in the uniformity.

During the course of the study a great similarity was noted between average backfat thickness and the single measurement taken opposite the spinal process of the seventh rib. To test this, correlation coefficients were calculated between the two:

- (1) Total correlation between average backfat thickness and backfat thickness at the seventh rib = +0.94.
- (2) Within breed groups correlation between average backfat thickness and backfat thickness at the seventh rib = +0.92.

#### IV. RELATIONSHIPS BETWEEN RATE OF GROWTH AND CARCASS CHARACTERISTICS

##### Literature

DICKERSON (9), in a study of 578 Poland Chinas, 114 Danish Landrace, and 54 Landrace-Poland China cross-breds from the Iowa swine breeding

project, reported strong associations among the following characteristics:

1. rapid increase in weight
2. rapid fat deposition
3. low feed requirements
4. poor suckling ability

He found a positive correlation of +0.60 or more between rate of gain to 225 pounds and the degree of fatness, and a negative correlation of -0.60 to -0.70 between rapid fat deposition and feed requirements. These correlations and deductions were based on sire and line deviations within the above population, particularly within the Poland China group. As a result of the study Dickerson makes this statement: "Rapid fat deposition and low feed requirements tended to be caused by the same genes. . . ."

On the other hand Dickerson in the same work reported very low correlations between rate of gain and yield of lean cuts, yield of fat cuts, and index of fat when using nonheritable deviations among litter mates.

Blunn and Baker (3), from data on Duroc Jersey pigs from the Nebraska swine breeding project, found these rather low correlations:

1. Depth of backfat and rate of gain from weaning to 112 days of age, +0.167.
2. Depth of backfat and rate of gain from 112 days of age to slaughter, +0.285.
3. Depth of backfat and total rate of gain from weaning to slaughter, +0.290.

The pigs used in the Nebraska experiment ranged in slaughter weight from 208 to 255 pounds, but no adjustment was reported for differences in the slaughter weight. Also, rather low correlations were found between rate of gain and ham circumference and between rate of gain and length of ham. The authors reported no significant genetic correlations between the above factors. They state, "These results with Duroc Jersey swine seem to indicate less genetic but more environmental association between rapid gains and fatness than has been found in Poland Chinas (Dickerson). This may indicate a breed difference in the relation between fatness and rate of gain."

Winters, Sierk, and Cummings (30) studied the effect of the plane of nutri-

tion on carcass quality in swine, using one of the groups of hogs included in this study. They found that when allowances were made for maintenance the pigs on a restricted feed intake required less feed for gain and had a greater tendency to convert this feed into muscle and bone rather than fat than pigs full fed. A smaller amount of nutrients was required to produce a pound of lean meat than a pound of fat. These workers suggest that, if this is the case, selection of breeding stock on the basis of economy of gain should be effective as a means of selecting animals that will yield a lean carcass.

Lush (15) reported very low correlations between daily rate of gain in Danish swine and yield of export bacon, thickness of backfat, thickness of belly, and body length. The correlations between feed per unit of gain and the same carcass characteristics were also very low.

Crampton (7) found no significant correlation between early rate of gain (eight weeks to 100 pounds) and degree of leanness of the carcass, nor between early rate of gain and length of side in Canadian bacon pigs. Stothart (25), using data from Canadian bacon pigs, found no correlation between the maturity index (rate of growth) and carcass excellence.

Donald (10) reported that length of leg and loin increased as weaning weight and carcass weight increased, but he found no association between length of leg or loin and rate of growth or changes in rate of growth. His work also showed that thickness of shoulder fat was negatively correlated with weaning weight and was unaffected by rate of growth or changes in the rate of growth.

Donald was working with two groups of pigs of different genetic origins. In one group he observed a tendency for thick backfat above the last rib to be associated with fast growth and for

thick backfat over the rump muscle to be associated with fast growth in the other group. In both groups of pigs, breadth of the "eye muscle" appeared to be independent of growth rate, changes in growth rate, weaning weight, and carcass weight. Only a very slight tendency, falling short of significance, was found for the "eye muscle" to become thicker as the rate of decline in relative growth rate increased.

Callow and Kitchen (6) observed that as the growth rate of pigs increased, the average iodine number of the backfat decreased, indicating firmer fat. Callow (5) goes on to explain that the association between rapid gain and low iodine number (firmer fat) of the backfat is due to these facts: (1) the fast-gaining hog builds most of his fat from carbohydrates, and (2) the slow-gaining hog builds his fat mostly from fats and oils which tend to produce a soft pork.

## Experimental

Growth rate data were available on 465 hogs from the Minnesota swine breeding experiments and from the University of Minnesota purebred herds. These hogs constituted a part of those used in experiments outlined in the preceding sections and included various kinds of breeding listed in table 14. Each breed group retains its original symbol. These hogs ranged from 170 pounds to 280 pounds live weight at the time of slaughter and averaged 216.5 pounds.

The following growth factors and numerical symbols were used:

1. Weaning weight. All pigs in the Minnesota swine breeding project were weaned and weights were recorded at 56 days of age. Those from the University of Minnesota purebred herds were weaned at approximately eight weeks of age but no weight was recorded. Therefore,

their 56-day weights were calculated from their earliest post-weaning weights by the following formula:

$$\text{Actual weight} \times \frac{41}{\text{age in days} - 15} = \text{56-day weight}$$

2. Average daily rate of gain from weaning (56 days of age) up to live weight at the time of slaughter.
3. Age (in days) at which the pig reached 200 pounds live weight.
4. Average daily rate of gain from weaning (56 days of age) to 112 days of age. In the sections to follow, this growth-rate factor will be called the "growth rate during the first period following weaning" or merely the "growth rate during the first period."
5. Average daily rate of gain from 112 days of age to slaughter weight. This will be called the "growth rate during the second period."
6. Weight at 112 days of age.
7. Live weight at the time of slaughter.

With the exception of 42 pigs on which only weaning and slaughter weights were available, the above growth factors were complete for each pig. Of the 42, two were from the C line of Poland Chinas, 21 were fall pigs from the Minnesota No. 1 line, and 19 were fall pigs of C-1 breeding. These differences in completeness of growth data are noted in table 14 and have been accounted for in the analyses to follow.

Simple and partial correlations were calculated from analyses of covariance between the above growth-rate factors and yield of five primal cuts (F), index of fat cuts (L), and length of carcass (C). Both total and within breed group correlations were used.

In order to make the above carcass characteristics and performance data comparable among the different groups in this phase of the study, corrections were made for differences in live weight at the time of slaughter.

Table 14. Averages for Carcass Yields and Length and for Growth Rate on 465 Hogs by Breed Groups

Breed groups	No.	Five primal cuts*	Index of fat cuts*	Length of carcass†	Weaning weight	Daily rate of gain—weaning to slaughter†	Age at 200 pounds	Daily rate of gain		Weight at 112 days
								First period	Second period†	
		per cent	per cent	inches	pounds	pounds	days	pounds	pounds	pounds
V	20	71.39	16.82	29.8	30.3	1.42	176	1.14	1.64	94
A	32	71.24	16.55	29.7	32.1	1.49	167	1.24	1.74	102
B	4	70.29	16.28	30.5	31.3	1.41	167	1.28	1.55	103
BS	6	68.81	19.43	30.0	38.8	1.52	152	1.39	1.68	117
C <sub>1</sub>	6	68.32	18.98	29.6	37.5	1.42	174	1.09	1.69	98
C <sub>2</sub>	2	68.18	23.49	30.8	34.0	1.66	166	1.30	1.96	107
C <sub>3</sub>	7	68.91	18.24	29.5	30.0	1.47	171	1.05	1.81	89
C	68	70.81	17.58	29.7	32.9	1.46	171	1.29	1.60	105
C	70	70.80	17.59	29.7	33.0	1.45	.....	.....	.....	.....
C-M	1	69.99	15.80	28.9	30.0	1.70	160	1.52	1.83	115
V-BS-WL	5	70.77	15.72	29.9	37.8	1.80	145	1.72	1.88	134
No. 1	4	68.50	19.58	31.3	30.8	1.28	176	1.32	1.30	105
No. 1	25	70.53	18.59	31.3	34.4	1.36	.....	.....	.....	.....
No. 2	4	71.00	16.18	31.9	24.8	1.45	173	1.00	1.79	81
1-V	15	69.02	18.37	30.5	44.1	1.65	150	1.54	1.79	131
1-V-1	5	70.56	19.15	30.9	40.8	1.82	148	1.61	2.04	131
V-1-V-1	7	71.21	17.31	30.5	38.0	1.70	152	1.51	1.95	123
1-M	14	68.40	19.54	30.1	47.0	1.61	147	1.46	1.81	129
1-1-M	8	70.64	18.42	30.5	39.8	1.69	154	1.38	2.02	117
M-1-1-M	7	70.73	18.06	29.7	45.7	1.66	150	1.38	2.01	123
2-M	7	71.34	15.84	30.1	37.7	1.59	159	1.25	1.94	108
M-2-M	24	71.50	16.64	29.7	39.3	1.47	168	1.12	1.77	102
2-V	6	71.18	16.30	30.5	46.5	1.68	152	1.42	1.95	126
V-2-V	6	71.24	16.04	29.8	37.2	1.56	162	1.15	1.97	102
2-ML	2	69.91	17.37	31.6	30.0	1.30	178	1.17	1.38	96
2-BS	1	72.18	16.83	30.8	32.0	1.32	160	1.30	1.40	105

\* Means adjusted for differences in live weight at the time of slaughter (average live weight = 216.5 pounds). The percentages are based on cold weight of the carcass dressed packer style.

† Means adjusted for differences in live weight at time of slaughter (average live weight = 216.5 pounds).

Table 14. Averages for Carcass Yields and Length and for Growth Rate on 465 Hogs by Breed Groups—Continued

Breed groups	No.	Five primal cuts*	Index of fat cuts*	Length of carcass†	Weaning weight	Daily rate of gain—weaning to slaughter†	Age at 200 pounds	Daily rate of gain		Weight at 112 days
								First period	Second period†	
		per cent	per cent	inches	pounds	pounds	days	pounds	pounds	pounds
2-1	21	69.81	18.34	31.0	44.4	1.70	150	1.46	1.97	126
2-2-1	4	72.05	17.46	29.6	33.8	1.95	145	1.78	2.19	133
2-V-1	1	69.63	16.30	31.0	58.0	1.44	155	1.25	1.64	128
V-2-1	4	71.99	18.70	30.1	33.8	1.71	155	1.38	2.07	111
1-2-V-1	2	69.92	19.46	30.9	39.0	1.61	159	1.40	1.82	117
V-1-2-V-1	2	72.24	16.37	30.7	35.5	1.44	169	1.19	1.63	102
C-1	3	72.65	17.49	30.5	45.7	1.87	141	1.64	2.21	137
C-1	22	71.50	17.97	30.9	41.0	1.34	.....	.....	.....	.....
PC	8	69.55	20.04	30.0	35.0	1.35	180	1.12	1.54	98
CW	19	67.13	23.36	29.0	32.7	1.29	192	.99	1.48	88
DJ	25	68.97	21.37	29.5	33.4	1.39	174	1.17	1.57	99
PC-1	4	70.23	18.84	28.9	26.0	1.24	202	.86	1.46	74
PC-2	5	71.48	16.80	29.3	29.6	1.21	201	1.02	1.33	86
PC-3	6	70.17	16.73	29.0	31.5	1.15	212	.63	1.43	67
PC-4	6	72.61	14.84	29.3	28.2	.97	234	.64	1.13	64
CW-1	7	68.40	21.11	29.2	24.7	1.29	200	.89	1.52	74
CW-2	7	70.18	18.75	29.0	28.6	1.11	219	.98	1.16	84
CW-3	8	70.11	18.77	28.8	29.9	1.07	225	.63	1.28	65
CW-4	8	72.19	17.15	28.6	30.5	.88	257	.62	.99	65
DJ-1	5	69.68	20.86	29.3	25.4	1.34	185	.87	1.64	74
DJ-2	5	69.40	19.81	29.2	26.6	1.17	208	.91	1.30	78
DJ-3	6	68.87	19.21	28.7	26.0	1.04	234	.55	1.25	57
DJ-4	6	71.52	17.02	29.4	26.0	.87	272	.56	.99	57
Total	465	70.35	18.22	29.9	35.0	1.43	175	1.19	1.65	101

\* Means adjusted for differences in live weight at the time of slaughter (average live weight = 216.5 pounds). The percentages are based on cold weight of the carcass dressed packer style.

† Means adjusted for differences in live weight at time of slaughter (average live weight = 216.5 pounds).

The above measures of growth rate, along with averages for yield of the five primal cuts, index of fat cuts, and carcass length, are given for the different breed groups in table 14. Breed differences were highly significant for all of the factors, even when the above adjustments were made.

The simple and partial correlations in table 15 indicate the degree of relationship between the growth-rate factors studied and yield of the five primal cuts. Most of the correlations are non-significant and all are quite low—even those that show significance. Live weight is negatively correlated with yield of the five primal cuts to approximately the same degree as is carcass weight.

Within weight classes and breed groups, weaning weight showed a significant and positive correlation with

yield of the five primal cuts. When breed differences were eliminated, the hogs gaining fast from weaning to slaughter tended to yield carcasses with a low proportion of five primal cuts. But when additional adjustments were made for slaughter weight, just the opposite relationship appeared to be true. Not until corrections had been made for differences due to slaughter weight and breed groups, was the correlation significant between age at 200 pounds and yield of the five primal cuts.

Under these circumstances, indications were that the fast-growing pigs from birth to 200 pounds tended somewhat to produce good carcasses. Daily rate of gain from weaning to 112 days of age, daily rate of gain from 112 days to slaughter, and 112-day weight held no relationship to the yield of the five primal cuts.

Table 15. Simple and Partial Correlations Between Yield of Five Primal Cuts and Rate of Growth

Factors*	Total	Within breed groups	Factors*	Total	Within breed groups
F/1	.00	+.03	F/4.17	+.05	+.06
F/1.2	+.03	+.05	F/4.57	-.01	+.07
F/1.7	+.04	+.14†	F/5	-.01	-.10
F/1.27	+.02	+.13†	F/5.7	+.08	+.09
F/2	-.07	-.10‡	F/5.4	-.01	-.09
F/2.1	-.08	-.11‡	F/5.47	+.07	+.08
F/2.7	+.04	+.14†	F/6	-.02	-.04
F/2.17	+.03	+.13†	F/6.7	+.03	+.10
F/3	+.06	+.08	F/6.5	-.01	-.02
F/3.7	-.01	-.12‡	F/6.57	-.03	+.09
F/4	.00	-.04	F/7	-.32†	-.37†
F/4.1	+.02	-.04	F/7.1	-.32†	-.39†
F/4.7	+.04	+.08	F/7.2	-.31†	-.38†
F/4.5	.00	-.02	F/7.12	-.31†	-.40†

\* Factors:

F = yield of five primal cuts in per cent of the cold carcass weight.

1 = weaning weight (56 days of age).

2 = daily rate of gain from weaning (56 days) to slaughter weight.

3 = age (in days) at the time the pig reached 200 pounds.

4 = daily rate of gain from weaning (56 days) to 112 days of age.

5 = daily rate of gain from 112 days of age to slaughter weight.

6 = weight at 112 days.

7 = live weight at the time of slaughter.

† Significant at one per cent level.

‡ Significant at five per cent level.

Table 16. Simple and Partial Correlations Between Index of Fat Cuts and Rate of Growth

Factors*	Total	Within breed groups	Factors*	Total	Within breed groups
L/1	-.02	+.04	L/4.17	-.08	-.07
L/1.2	-.03	.00	L/4.57	-.03	-.07
L/1.7	-.06	-.08			
L/1.27	-.02	-.08	L/5	-.01	+.18†
			L/5.7	-.10‡	-.02
L/2	+.01	+.19†	L/5.4	+.02	+.17†
L/2.1	+.03	+.18†	L/5.47	-.06	-.01
L/2.7	-.10‡	-.07			
L/2.17	-.08	-.07	L/6	-.04	+.08
			L/6.7	-.08	-.08
L/3	-.01	-.16†	L/6.5	-.04	+.04
L/3.7	+.06	+.06	L/6.57	-.03	-.08
L/4	-.04	+.06	L/7	+.30†	+.44†
L/4.1	-.05	+.04	L/7.1	+.31†	+.44†
L/4.7	-.09	-.08	L/7.2	+.32†	+.41†
L/4.5	-.05	-.02	L/7.12	+.32†	+.41†

\* Factors:

- L = index of fat cuts in per cent of the cold carcass weight.
- 1 = weaning weight (56 days of age).
- 2 = daily rate of gain from weaning (56 days) to slaughter weight.
- 3 = age (in days) at the time the pig reached 200 pounds.
- 4 = daily rate of gain from weaning (56 days) to 112 days of age.
- 5 = daily rate of gain from 112 days of age to slaughter weight.
- 6 = weight at 112 days.
- 7 = live weight at the time of slaughter.

† Significant at one per cent level.

‡ Significant at five per cent level.

Table 17. Simple and Partial Correlations Between Carcass Length and Rate of Growth

Factors*	Total	Within breed groups	Factors*	Total	Within breed groups
C/1	+.35†	+.25†	C/4.17	+.35†	+.11‡
C/1.2	+.20†	+.19†	C/4.57	+.31†	+.13†
C/1.7	+.34†	+.11‡			
C/1.27	+.24†	+.11‡	C/5	+.46†	+.32†
			C/5.7	+.38†	+.03
C/2	+.44†	+.38†	C/5.4	+.25†	+.27†
C/2.1	+.34†	+.35†	C/5.47	+.14†	+.02
C/2.7	+.34†	+.04			
C/2.17	+.22†	+.03	C/6	+.47†	+.33†
			C/6.7	+.47†	+.15†
C/3	-.51†	-.40†	C/6.5	+.27†	+.28†
C/3.7	-.47†	-.12‡	C/6.57	+.32†	+.15†
C/4	+.45†	+.29†	C/7	+.48†	+.64†
C/4.1	+.34†	+.23†	C/7.1	+.48†	+.61†
C/4.7	+.46†	+.14†	C/7.2	+.40†	+.55†
C/4.5	+.24†	+.23†	C/7.12	+.41†	+.54†

\* Factors:

- C = length of carcass (inches).
- 1 = weaning weight (56 days of age).
- 2 = daily rate of gain from weaning (56 days) to slaughter weight.
- 3 = age (in days) at the time the pig reached 200 pounds.
- 4 = daily rate of gain from weaning (56 days) to 112 days of age.
- 5 = daily rate of gain from 112 days of age to slaughter weight.
- 6 = weight at 112 days.
- 7 = live weight at the time of slaughter.

† Significant at one per cent level.

‡ Significant at five per cent level.

In table 16 are given the simple and partial correlations between the same growth-rate factors cited above and the index of fat cuts. Apparently weaning weight was not related to this carcass characteristic. Total rate of gain was positively correlated with index of fat cuts within breed groups until adjustments were made for differences in slaughter weight; then the relationship became nonsignificant. Again, after corrections were made for live weight, there was no association between age at 200 pounds and index of fat cuts.

No significant correlation existed between rate of gain immediately following weaning and fatness of the carcasses. An increase in the rate of gain after 112 days of age tended slightly to increase the degree of fatness, but not when differences between breed groups and weight classes had been taken into account. As with weaning weight and early rate of gain, the weight at 112 days of age showed no relationship with index of fat cuts. The index of fat cuts was increased with an increase in slaughter weight.

The effects of these growth rate factors on length of carcass are reported

in table 17. In general, rapid rate of growth during early life up to 112 days of age tended to increase the length of carcass even when this length was corrected for differences among breed groups and in slaughter weight. Average daily rate of gain from weaning to slaughter weight and rate of gain from 112 days to slaughter had no relationship to carcass length within breed groups and within slaughter weight classes. Carcass length increased with an increase in the slaughter weight.

Figures 15, 16, 19, 20, 21, and 22 show the breed group means for yield of the five primal cuts and index of fat cuts (both corrected for differences in live weight at the time of slaughter) in relation to the growth rate factors discussed above. Adjustments have also been made to a common slaughter weight for (1) average daily rate of gain from weaning to slaughter, and (2) average daily rate of gain from 112 days of age to slaughter weight.

Many of the closely related breed groups, especially the crossbreds, have been recombined into larger groups and indicated by the lines used in the crossing combinations. The C<sub>1</sub>, C<sub>2</sub>, and C<sub>3</sub> lines of Poland Chinas, which were

Table 18. Partial Correlations of Daily Rate of Gain from Weaning to Slaughter Weight with Yield of Five Primal Cuts and with Index of Fat Cuts, Within Breed Groups

Breed group	No.	F/2.7*	L/2.7†
V and A lines .....	52	+ .16	+ .18
C line .....	70	+ .27‡	- .17
Minn. No. 1 .....	25	+ .33	- .45‡
Minn. No. 2 .....	4	+ .51	- .48
Outbred PC .....	12	- .01	+ .03
Outbred CW .....	26	- .11	.00
Outbred DJ .....	30	- .08	- .20
Crossbreds:			
1-PC combinations .....	78	- .12	+ .01
2-PC combinations .....	46	+ .11	- .15
2-1 combinations .....	25	+ .33	- .11
V-2-1 combinations .....	9	+ .06	+ .70

\* Correlation coefficients between average daily gain from weaning (56 days) to slaughter weight and yield of five primal cuts with slaughter weight held constant.

† Correlation coefficients between average daily gain from weaning (56 days) to slaughter weight and index of fat cuts with slaughter weight held constant.

‡ Significant at five per cent level.

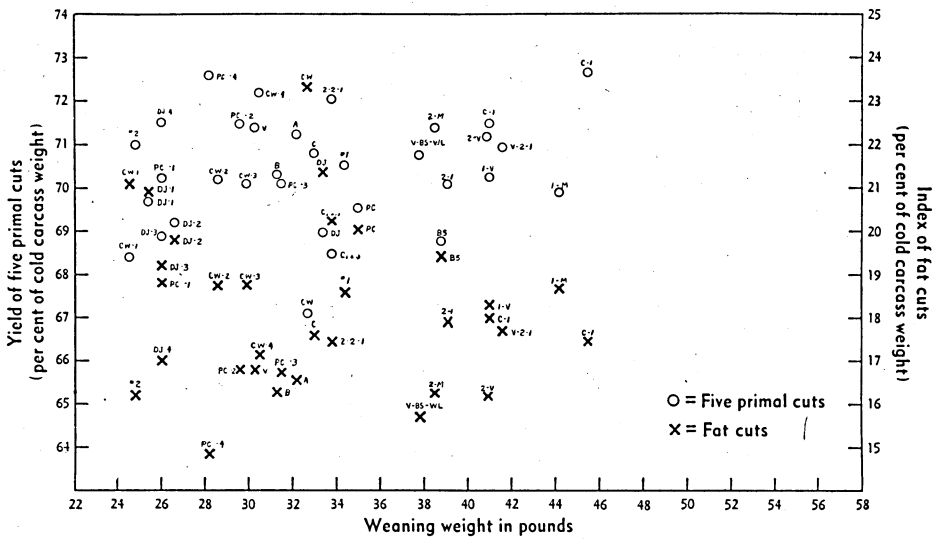


Fig. 15. Mean carcass yields for each breed group as related to its mean weaning weight. Yield of five primal cuts and index of fat cuts have been adjusted for differences in slaughter weight.

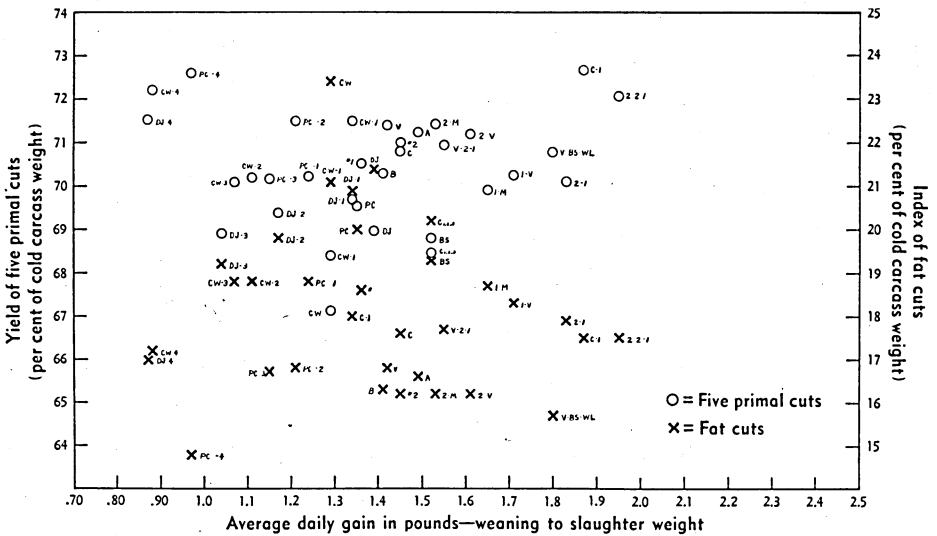


Fig. 16. Mean carcass yields for each breed group as related to its mean daily gain from weaning to slaughter. The factors have been adjusted for differences in slaughter weight.

very similar, have been grouped together ( $C_1, 2, 3$ ). All of the pigs used in the self- and restricted-feeding trial have been separated by breed and lot in order to observe the combination effects of breeding and plane of nutrition.

Figure 17 is a scatter diagram showing the relationship between yield of the five primal cuts and average daily rate of gain from weaning to slaughter weight. Both factors have been corrected for differences in live weight

at slaughter. Each dot represents an individual pig; none of those used in the self- and restricted-feeding trial have been included.

Each circle was drawn to enclose the limits in the scatter of each breed group indicated. It must be understood that only the extremes were taken into consideration in drawing the circles and the center of each circle does not necessarily represent the group mean.

Figure 18 is based on the same plan as figure 17 but shows the relationship

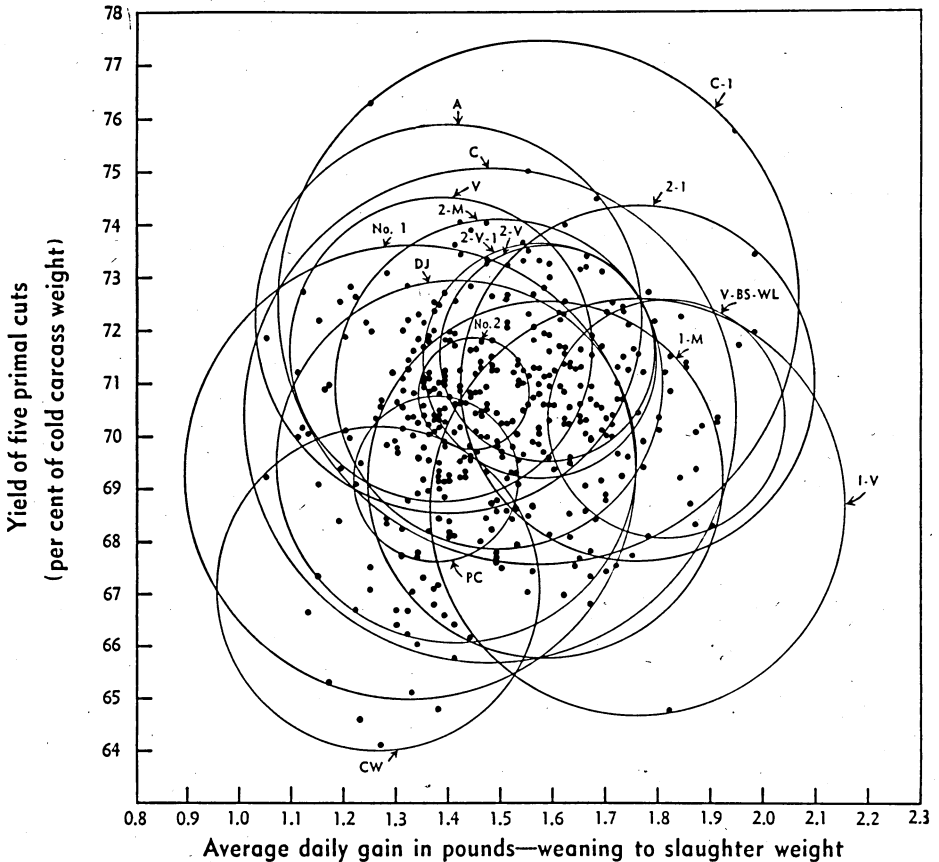


Fig. 17. Scatter diagram showing relationship of yield of the five primal cuts to rate of gain from weaning to slaughter. Both factors have been adjusted for differences in slaughter weight. Circles enclose the limits of the breed groups indicated (392 hogs).

of the index of fat cuts to daily rate of gain from weaning to slaughter weight. The same pigs have been used and the same breed groups represented.

By studying both of these diagrams, along with figure 16, one can readily see that certain breed groups were quite different from one another in both growth rate and carcass yield. Also, carcass yield was not necessarily correlated with growth rate between different genotypes. On the other hand,

considerable overlapping occurred between other breed groups.

Table 18 has been prepared to test the differences in the associations between growth rate and carcass yields within the various breed groups. The yield of five primal cuts and the index of fat cuts have been correlated with average daily gain from weaning to slaughter, with adjustments made for differences in slaughter weight. Only two statistically significant correlation

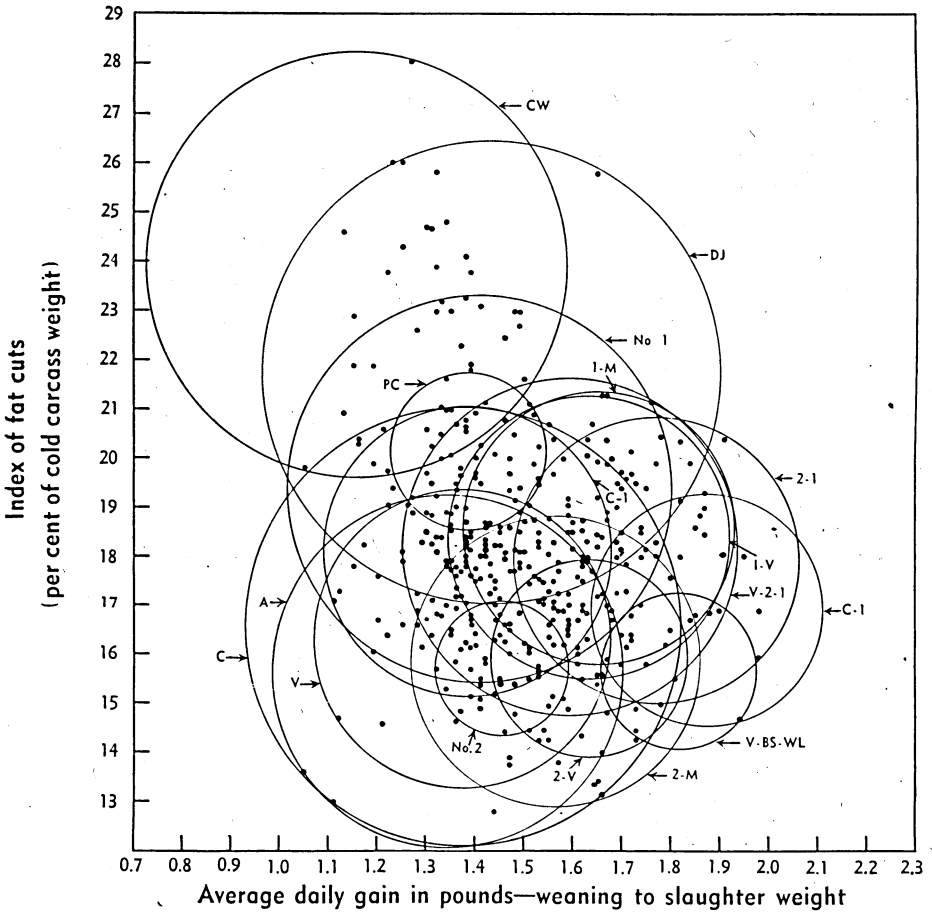


Fig. 18. Scatter diagram showing the relationship of the index of fat cuts to rate of gain from weaning to slaughter. Both factors have been adjusted for differences in slaughter weight. Circles enclose the limits of the breed groups indicated (392 hogs).

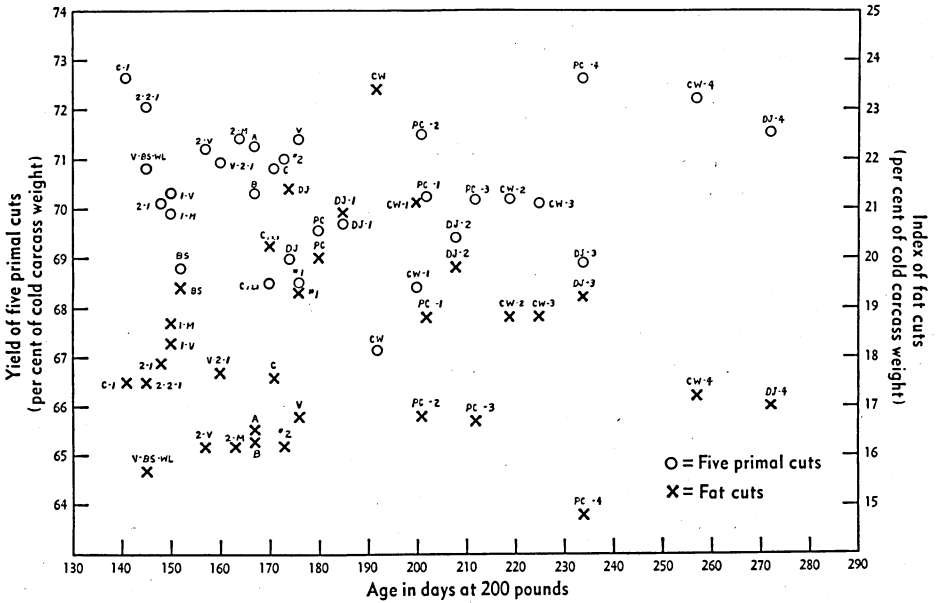


Fig. 19. Mean carcass yields for each breed group as related to its mean age at 200 pounds. Yield of the five primal cuts and index of fat cuts have been adjusted for differences in slaughter weight.

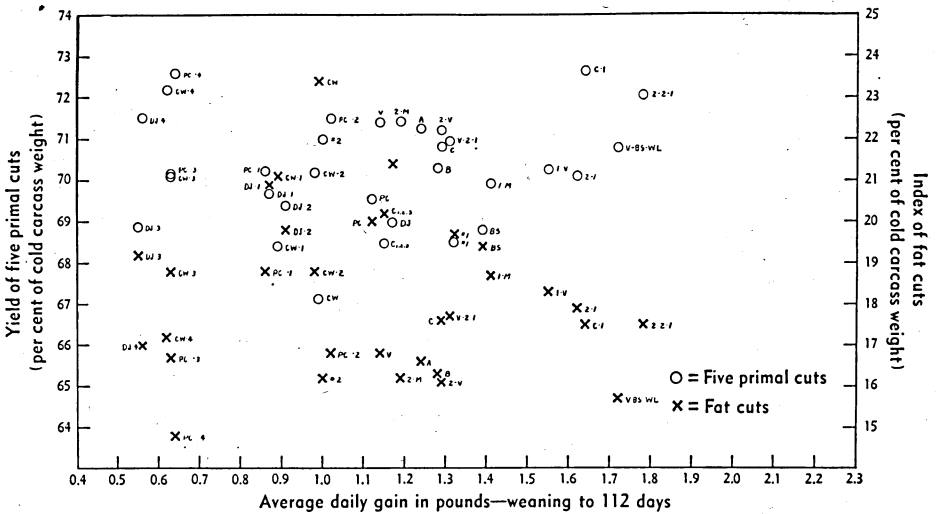


Fig. 20. Mean carcass yields for each breed group as related to its mean growth rate from weaning to 112 days. Yield of five primal cuts and index of fat cuts have been adjusted for differences in slaughter weight.

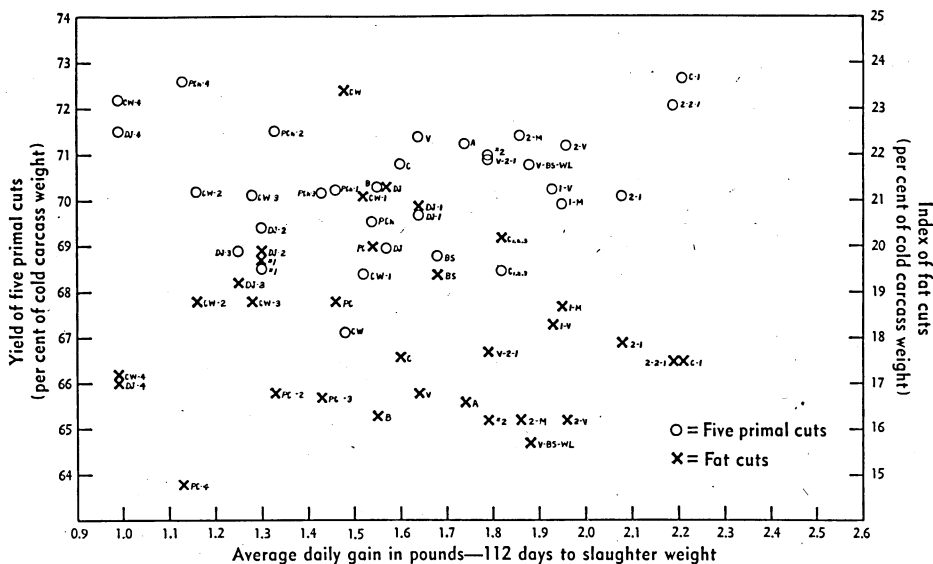


Fig. 21. Mean carcass yields for each breed group as related to its mean growth rate from 112 days to slaughter. All three factors have been adjusted for differences in slaughter weight.

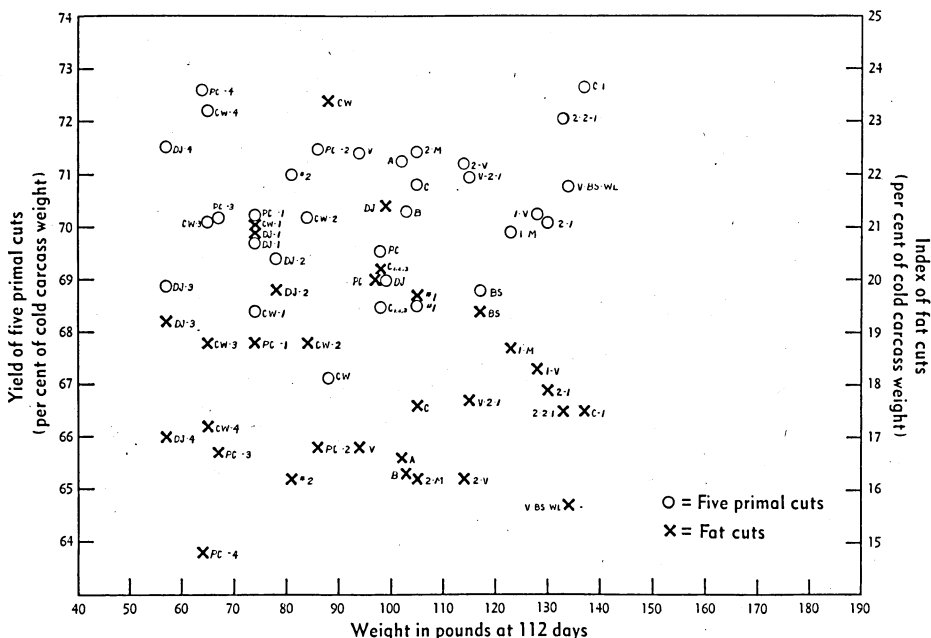


Fig. 22. Mean carcass yields for each breed group as related to its mean weight at 112 days. Yield of the five primal cuts and index of fat cuts have been adjusted for differences in slaughter weight.

coefficients appeared: a positive association between rate of gain and yield of five primal cuts in the C line of Poland Chinas, and a negative association between rate of gain and index of

fat cuts in the Minnesota No. 1 line. For the most part, the relationships between growth rate and carcass yields were not significant, even when each of the groups was considered separately.

## V. USE OF THE T FACTOR TO PREDICT THE YIELD OF THE FIVE PRIMAL CUTS

**A**FTER ALL of the data had been collected for the studies reported in Part III, three additional groups of hogs from the Minnesota swine breeding project were slaughtered. The same procedures as before (at Wilson Packing Company of Albert Lea, Minnesota) were used and the same cut-out data and carcass measurements were collected.

From these data the T factors (see page 33) were calculated in order to predict the yields of the five primal cuts, and these predictions were then compared with the actual yields. This comparison was made to see how accurately the T factor could be used to predict carcass yields on hogs other than those from which the original relationships were determined.

The three slaughter groups were as follows:

**Group I** consisted of 83 head killed in the fall of 1948, including hogs from the M line of Poland Chinas, the Minnesota No. 1 line, and crosses between the Minnesota No. 1 line, Minnesota No. 2 line, and inbred lines of Poland Chinas.

**Group II** was made up of 45 hogs slaughtered in the spring of 1949, including hogs from the Minnesota No. 1 line and experimental hogs. The latter were used in a feeding trial in which Lots 1 and 3 and Lots 2 and 4 constituted the two important groups as far as treatment was concerned.

**Group III**, composed of 144 hogs, was slaughtered in the fall of 1949 and in-

cluded those from inbred Poland China lines (M, V, A, and C lines), from Minnesota No. 1 and No. 2 lines, and from crossbred groups where these inbred lines had been used.

Table 19 gives the actual and predicted yields of the five primal cuts, the differences between these yields, and the expected errors by slaughter groups and breed groups within slaughters. For the most part, the yields from hogs in Groups I and III were predicted within the limits of error. The predicted yields for hogs in Group II were all higher than the actual yields and beyond the limits of error. The only justifiable explanation for this discrepancy is that the carcasses from this group were probably cut into the wholesale cuts somewhat differently from those of other slaughters. This could easily occur with changes in demand for pork products.

The necessity for the use of consistent procedures in cutting carcasses has been borne out in the authors' experience before, when trying to compare carcass yield data from different packing plants. From those experiences it was found impossible to make such comparisons. Carcass cutting is an art in itself, and variations in procedure are important trade secrets.

An analysis of variance of differences between the predicted and actual yields of the five primal cuts, using the data from the three slaughters, showed a highly significant difference ( $F=7.08$ ) between slaughter groups and no sig-

Table 19. A Comparison of the Actual Yields of Five Primal Cuts with the Predicted Yields of Five Primal Cuts from Hogs Slaughtered in the Fall of 1948, Spring of 1949, and Fall of 1949, Using the T Factor for Prediction

Slaughter groups	Breed groups	Average cold carcass weight	Actual yield of five primal cuts*	No.	Predicted yield of five primal cuts*	Difference in predicted and actual yields—group av. basis	Expected error for the group†	Average difference in predicted and actual yields—indiv. basis‡
I—Fall, 1948	M	148.0	68.84	4	70.86	+2.02	±0.77	±2.09
	Minn. No. 1	153.8	69.21	9	69.79	+0.58	±0.51	±1.15
	1-2	151.5	70.48	6	69.76	-0.72	±0.63	±1.50
	1-PC	151.6	70.22	32	69.94	-0.28	±0.27	±0.97
	2-PC	140.4	71.11	12	70.98	-0.13	±0.44	±1.14
	1-2-PC	156.9	70.30	19	70.71	+0.41	±0.35	±1.08
	3-line cross (PC)	144.0	69.10	1	70.40	+1.30	±1.54	±1.30
	Total—Group I	151.2	70.20	83	70.28	+0.08	±0.17	±1.13
II—Spring, 1949	Lots 1 and 3	143.6	69.47	14	70.24	+0.77	±0.41	±1.61
	Lots 2 and 4	143.6	67.21	13	68.97	+1.76	±0.43	±1.92
	Minn. No. 1 (NC Sta.)	149.3	68.71	10	70.67	+1.96	±0.49	±1.99
	Minn. No. 1 (SE Sta.)	141.9	69.53	8	70.46	+0.93	±0.54	±1.16
	Total—Group II	144.6	68.66	45	70.01	+1.35	±0.23	±1.70
III—Fall, 1949	M	160.0	69.66	1	71.30	+1.64	±1.54	±1.64
	V	149.1	70.40	4	70.49	+0.09	±0.77	±1.02
	A	136.3	71.66	16	70.82	-0.84	±0.39	±1.42
	C	144.4	70.85	15	71.71	+0.86	±0.40	±1.10
	Minn. No. 1	150.3	69.23	19	70.61	+1.38	±0.35	±1.78
	Minn. No. 2	134.8	71.76	9	71.74	-0.02	±0.51	±0.95
	1-PC	139.6	71.18	19	71.13	-0.05	±0.35	±0.96
	1-2-PC (inbred sires)	145.3	70.18	37	70.36	+0.18	±0.25	±0.89
	1-2-PC (crossbred sires)	140.6	70.98	19	71.65	+0.67	±0.35	±0.98
	1-2	137.3	70.66	2	70.97	+0.31	±1.09	±0.43
	2-PC	155.8	71.31	3	71.30	-0.01	±0.89	±0.59
	Total—Group III	143.2	70.66	144	70.98	+0.32	±0.13	±1.11

\* Per cent, based on cold weight of the carcass dressed packer style.

† Expected errors calculated as follows:  $\frac{1}{\sqrt{N}} \times 1.54$ .

‡ Standard error of estimate  $\pm 1.54$ .

nificant difference between breed groups within slaughters ( $F=1.11$ ). However, on further examination of table 19 it would appear that the predicted yields of the carcasses from the Minnesota No. 1 line and from the M line of Poland Chinas deviated from the actual cut-out to a greater extent than any of the other groups. This might be due to the fact that these two lines represented the extremes in type—the pigs from the M line were the shortest in body length and those from the No. 1 line were the longest.

On the other hand, when the data in the scatter diagram showing the relationship between the T factor and yield of five primal cuts (figure 13) were analyzed further, there was no

indication that length, weight of carcass, or average backfat thickness played any significant part in accounting for the deviations from the regression line. There was some indication that breeding was an influencing factor in this respect, but the data were insufficient to establish separate regressions for each group or even for groups that deviated from the mean line to the greatest extent.

Correlations were low between the T factor and yield of five primal cuts calculated separately, using all the data available on carcasses from the Minnesota No. 1 line and M line. That for the M line was  $+0.17$  (nonsignificant), and for the Minnesota No. 1 it was  $-0.31$  (significant at the 5 per cent level).

## DISCUSSION OF THE RESULTS

**T**HE EFFECTS of breeding on carcass composition in swine are quite apparent from the results given in Part I. Real differences between the various test groups existed in the yield of the five primal cuts and index of fat cuts as well as the various cuts comprising these two classes. Real differences also existed between groups in relation to the carcass measurements taken.

In actual magnitude the percentage differences in yields of the various cuts are small, yet when one considers that several thousand hogs are slaughtered and processed every day by our packing plants, one per cent variation in the five primal cuts or fat cuts can amount to a great deal in profit or loss. In addition, a difference of one per cent or less in average yield seems to be sufficient in separating most of the breed groups studied.

Most of the groups of hogs from the Minnesota swine breeding project

yielded superior carcasses compared with hogs selected from the regular market run and with outbred hogs from three of the most popular breeds used today. One group from an outside source (the Schechter herd) also yielded very good carcasses, but it should be remembered that they were all Minnesota No. 1 top crosses.

It would be difficult to say what was the exact breeding of the hogs from the market runs, but they appeared to be of mixed breeding (either grades or crossbreds) where the more popular breeds had been used; i.e., Duroc Jersey, Poland China, Chester White, Spotted Poland China, and Hampshire.

Some of the poorest carcasses came from a few of the inbred Poland China lines of the Minnesota project, but these lines have since been discontinued in favor of better performing lines (A, V, C, and B lines) which produced good carcasses in these tests. An exception is the M line, which is being

continued because of its extremely high degree of inbreeding ( $F_x=.80$ ) even though its performance and carcass qualities are not up to par with the other Poland China lines. When this line is crossed with other Minnesota lines, the carcass yields and quality are markedly improved (see table 3 and figures 4-7). Line crosses within the Poland Chinas, especially those including the M line, did not yield particularly outstanding carcasses.

The best carcasses, when yields and quality of the meat were taken into consideration, came from the crossbred groups. Even one group of crosses between Poland China lines (V-BS-WL) produced outstanding carcasses.

Those from the crossbreds were not the best on the basis of the yield data and measurements alone because, in most cases, they showed intermediacy between the two parental lines in these respects. However, they were better than any one of the parental lines used because of the combination of traits exhibited.

As was brought out before whenever the Minnesota No. 1 line was used in a cross, the length of the carcass, the yield of bacon, and the quality of bacon were particularly increased over that of the other line. Whenever the Minnesota No. 2 line was used, the yield of loin and the thickness of lean were increased and the amount of excess fat was markedly reduced; and whenever one of the Poland China lines was used, the yield of ham was increased.

The carcasses from hogs of 1-2-V, 2-1, and C-1 breeding were the most outstanding ones in the opinion of those handling them at the time of collecting these data, yet that fact is not entirely brought out by yields alone as calculated above.

The fattest carcasses came from the outbred groups of Chester Whites and Duroc Jerseys, and in yield of the five

primal cuts they were among the lowest groups studied. The outbred Poland Chinas were fairly good in yield of the five primal cuts but fatter than most of the inbred lines of Poland Chinas. It is acknowledged that the groups of outbreds may not represent their respective breeds in their entirety, yet they were taken as typical samples from herds developed by a continuous system of outcrossing in which breeding stock had been used from a number of sources within each breed.

Even though yield of the five primal cuts was found to be significantly correlated with the degree of leanness of the carcass (Aunan and Winters, 1) it should be pointed out that yield data alone are quite inadequate in appraising carcass quality in swine. There is an additional need for standard technical procedures which will readily measure the internal characteristics of the carcasses without mutilation to the saleable cuts and which can be applied to large numbers within a reasonable length of time if further improvement in pork quality is desired.

Improvement through breeding and feeding can go only so far unless some accurate means is provided for measuring what is really wanted. The percentage yield of the valuable cuts is a desirable measure but not the whole story, because a wasteful carcass with a low yield of the primal cuts is no better than a high-yielding carcass from which the primal cuts are not of the desirable quality.

The following examples illustrate the above weaknesses:

The outbred Duroc Jerseys, the group in this study which produced the highest percentage of bellies, also produced the poorest quality of bellies because of extremely high content of fat and low amount of lean. This high yield of bellies was also reflected in a higher yield of five primal cuts than was deserving of the group if the yield of primal cuts

is to be used exclusively as the means of estimating carcass excellence.

The observation was that the 1-2 crossbreeds produced carcasses that were best in quality of meat, but there is no way of detecting this fact from the yield figures. Carcasses with a high yield of shoulder and low yield of ham, belly, or loin will show as high a yield of five primal cuts as the better carcasses where the shoulder yield is low and other cuts high.

The fact that the Minnesota No. 1 pigs and their crosses produce a higher amount of internal fat (leaf fat) tends to make it appear from the fat indexes that their carcasses were actually fatter than would be indicated by the amount of subcutaneous fat. Hogs from Lot 4 of the self- and restricted-feeding trial were some of the highest yielding in the study, yet their carcasses were soft and watery and showed too high a proportion of bone.

Davidson *et al.* (8) found that the hog carcass had to be cut and appraised from the appearance of the internal characters, some of which could not be accurately evaluated by measurement alone. Some of the external characters also could not be evaluated simply by measurement. These workers set up standards for optimum backfat thickness in recognition of the fact that underfinished carcasses lacked good eating and keeping qualities.

The results of the self- and restricted-feeding trial show that carcass yields can be altered by subjecting similar genetic materials to different environmental conditions. By restricting the feed intake to three per cent of the body weight (Lot 4) instead of allowing the pigs to eat all they wanted (Lot 1), the yield of the five primal cuts was increased 2.4 per cent and the fat cuts were reduced 3.6 per cent.

The trial results indicated no difference in the yield of five primal cuts between Lot 1 (full feeding continu-

ously to slaughter) and Lot 3 (restricted feeding to 125 pounds followed by full feeding to slaughter), yet the latter group produced less proportional weight in fat cuts. By full feeding up to 125 pounds followed by restricted feeding to slaughter (Lot 2), the yield of the five primal cuts was increased and the fat cuts decreased. But this increase in lean cuts and decrease in fat cuts was not as severe as when restricted feeding was used during the entire period (see table 6).

These results are not in keeping with those of McMeekan and Hammond (21 and 22) but there is no reason that they should. Pigs used in their study were subjected to the various treatments from birth through a very critical period of growth, while this trial was not started until the pigs were about 80 days old.

Another point of difference is that McMeekan and Hammond fed their pigs to follow definite growth curves so that Lots 2 and 3 would reach 200 pounds at the same age. The poorest carcasses and the ones which contained the most fat came from the group stunted during early life and then fed for rapid gains during the latter phase (Lot 3). They considered that their best carcasses came from the group fed for rapid gains early in life and then restricted in order to minimize the amount of fat increase. The poorest carcasses in the above trial came from Lot 1 (too fat) and from Lot 4 (too thin and soft).

The fact that the restricted pigs required less feed for growth and that the feed was converted into more lean than fat has been brought out in a preceding section and reported by Winters, Sierk, and Cummings (30).

The effect of the different levels of feeding on the three breeds of hogs used is quite interesting. Differences between breeds in yield of the five primal cuts are not significant even within lots, and the breeds did not tend to stay in the

same order with different treatments. However, this interaction was not statistically significant. On the other hand, the Poland Chinas consistently yielded less fat than either of the other two breeds, regardless of the method of feeding (figure 10).

In practically all groups the heavy pigs at the time of slaughter yielded fat carcasses with a low content of the five primal cuts. This fact was due in part to the fact that the heavy hogs had reached a later stage of development—fat tissue was increasing at a faster rate than lean tissue. The degree of association between weight and fatness was relatively low ( $r = +0.40$ ), suggesting that variation still existed where certain individuals and especially certain breed groups could be carried to heavier weights than others without danger of decreasing the value of the carcass.

On the other hand, there was still enough association between weight and fatness to indicate the need for making adjustments for differences in live weight and for running carcass tests at a constant weight in order to obtain reliable comparisons. In carcasses showing the same thickness of backfat, however, weight had practically no effect on the yields since the latter were calculated in percentages of the carcass weight.

The average backfat thickness and the T factor had the highest predictive values for yield of the five primal cuts and the index of fat cuts. It would seem that the T factor would be of more practical use than backfat thickness alone, even though the differences between the simple correlations were non-significant. Correlations of yields with the T factor were higher than those with backfat thickness alone and higher yet after adjustments were made for differences in weight. The T factor has combined both backfat thickness and length of carcass.

Even though the correlations indicated less effect from length than from backfat thickness on yields of five primal cuts or fat cuts, the importance of length of carcass should not be underestimated to the same degree in the final appraisal of carcass utility. Increased carcass length accomplishes two things of value which might be covered up to varying degrees in the total yield figure:

(1) Length will be reflected in longer bacons which will yield a higher percentage of sliced bacon, because usually the same amount of waste from bacon ends is produced in the slicing process regardless of the length of the slab; and (2) length is also reflected in a longer loin which in turn will yield a higher proportion of chops and roasts in the high-price bracket.

The T factor or backfat thickness alone should have greater value in predicting the average carcass yields from groups of carcasses than from individual ones, for then the errors of estimate (see figures 11, 12, 13, and 14) will be reduced to  $\frac{1}{\sqrt{N}} \times \text{S. E.}$  where N

equals the number of carcasses in the group. Apparently either factor can be used on carcasses of various weights or breeding without making adjustments.

Both the T factor and average backfat thickness were associated with the loss in skinning the hams, but variations in these associations apparently existed to a large extent in different breed groups. Neither the loss in skinning the hams nor the U factor had a high predictive value for the yield of five primal cuts or index of fat cuts. Very low associations, even though significant in most cases, were found between uniformity of backfat thickness and yield of the five primal cuts or the fat cuts.

The use of simple carcass measurements to predict yields apparently has limitations. The use of the T factor for such purposes was reasonably success-

time of slaughter, averaging 216.5 pounds. They represented the various inbred lines of Poland Chinas, the Minnesota No. 1 line, the Minnesota No. 2 line, and various combinations of crosses between these lines—all from the Minnesota swine breeding project. Other hogs used included these groups: (1) those from the general market runs coming from growers in the northern corn belt area, (2) outbred hogs of three of the most popular breeds from the University of Minnesota purebred herds which have been developed by a continuous system of outcrossing, and (3) hogs from a herd where Minnesota No. 1 boars were used in the last cross.

2. Real differences due to breeding were found among the groups in proportional yield of the five primal cuts, degree of fatness, yield of individual cuts, and carcass measurements.

3. Under normal feeding practices certain breed groups from the Minnesota swine breeding project produced carcasses yielding the highest percentage of the five primal cuts and the lowest degree of fatness. Crossbred groups were superior to the parental lines in carcass composition, not because their total yield of the five primal cuts was higher than the superior parent but because they combined the desirable carcass traits of both parents. When the Minnesota No. 1 line was used in a cross, the carcass length and the yield of high quality bacon were increased. When the Minnesota No. 2 line was used in a cross the yield of loin increased and the amount of excess fat decreased. The proportion of ham was increased when Poland China lines were used.

4. The carcasses with the lowest yields of five primal cuts came from some of the inbred lines of Poland Chinas and from the outbred groups. The fattest carcasses were produced by two of the outbred groups, Duroc Jerseys and Chester Whites.

5. The use of the total yield of the five primal cuts as the sole form of appraisal for carcass excellence was found inadequate.

6. Carcass composition was altered by subjecting similar genetic materials to different levels of food intake. In order for outbred hogs used in this phase of the study to make comparable yields of the five primal cuts and fat cuts to those from the best performing crossbred groups, it was necessary to restrict the feed intake for the outbred hogs to three per cent of their body weight and prolong the feeding period over a much longer time. When the outbreds were restricted in this way their carcasses still lacked complete development of muscular tissue. By making allowances for maintenance, however, it was found that less feed was required to produce a pound of lean than to produce a pound of fat.

7. Breed differences in the yield of the five primal cuts were not observed for different levels of feeding, but it was noted that the Poland China groups consistently produced less fat than either the Duroc Jerseys or the Chester Whites, regardless of the method of feeding. No interaction between breeds and method of feeding occurred in relation to carcass yields.

8. Average backfat thickness and the ratio of backfat thickness to length of carcass (T factor) showed high correlations with the yield of five primal cuts and the index of fat cuts. These relationships were applicable without making adjustments for breed differences or weight differences. An increase of one inch in the average backfat thickness indicated a decrease of five per cent in the yield of the five primal cuts and an increase of seven per cent in the index of fat cuts. A decrease in the T factor indicated an increase in the percentage yield of the five primal cuts and a decrease in the fat cuts. It has been suggested that the T factor rather

than backfat thickness alone be used for predictive purposes because carcass value is also influenced by its length.

9. The T factors calculated from carcass measurements on an additional 272 hogs slaughtered were used to predict the yields of five primal cuts. The predicted yields fell within the expected limits of error when compared with the actual yields for two of the slaughter groups but did not fit those from a third group. Changes in procedure of cutting on this third group are suggested as the probable cause for this discrepancy, yet there is also the indication that simple carcass measurements are not entirely satisfactory for exact predictions of yield and quality. It is suggested, however, that the T factor still be used to place groups of carcasses in relative order of commercial value.

10. Length of carcass did not show a high degree of relationship with the percentage yields of the five primal cuts or fat cuts, though the correlations were significant. Nevertheless, it has been pointed out that increased length is still a valuable characteristic of swine carcasses.

11. Yields of the five primal cuts and fat cuts were strongly correlated with carcass weight and live weight at the time of slaughter. Therefore, adjustments have been made when making comparisons between the various groups of different weights.

12. Uniformity of backfat thickness, the U factor, and loss in skinning hams showed relatively low relationships to carcass yields.

13. All of the growth rate factors showed very low associations with the yield of the five primal cuts as well as with the index of fat cuts. In most instances the correlations were non-significant. And even though significant positive trends existed between weaning weight and yield of the five primal cuts and between rate of gain from weaning to slaughter and yield of the five primal cuts, these correlations were still very low after adjustments were made for differences in weight and breed groups.

14. There was a slightly positive association between rate of growth and leanness of carcass within the C line of Poland Chinas and the Minnesota No. 1 line, but there was no relationship between the same characteristics within the other breed groups studied.

15. Rapid rate of gain early in life was reflected in an increase in carcass length.

16. Various combinations of growth rate characteristics and carcass characteristics were found to exist in the breed groups studied, yet the best carcasses came from those groups making the fastest gains from birth to slaughter. Their gains, however, were exceptionally high.

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