9

SELECTION FOR MAXIMUM LOIN EYE AREA AND MINIMUM BACKFAT THICKNESS IN DUROC SWINE

by

CHING HSONG CHANG

Diploma, Taiwan Provincial Ping-tung Institute of Agriculture, 1970

A MASTER'S THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

ANIMAL SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY

Manhattan, Kansas

1974

Approved by:

John D. Wheat
Major Professor

ACKNOWLEDGEMENT

The author wishes to express his sincere appreciation and thanks to Dr. John D. Wheat, major professor, for his assistance, guidance and encouragement during this study.

Appreciation is also extended to Dr. Donald H. Kropf, Dr. Robert R. Schalles, Dr. James V. Craig and Dr. Kenneth E. Kemp for their guidance and assistance in data procuring and statistical analysis.

The author wishes to extend special thanks to Dr. Don L. Good, head of the department, and Dr. Draftford Richardson, Chairman of Graduate Admission Committee, for their assistance and encouragement.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

The rapid rise in the standard of living and changes in dietary habits during the past three decades have greatly increased the demand for lean meat. To meet this demand, there has been intensive selection for more muscle and less fat in swine. At the same time, the producer must have prolific, rapid gaining pigs with low feed conversions if he is to economically produce this type of pig. Meat quality as well as quantity must be emphasized if selection results in progress toward this goal.

Heritability estimates for backfat thickness from previous studies varies from 0.12 to 0.84 (Lush, 1936; Blunn and Baker, 1947; Johansson and Korkman, 1950; Whatley, Jr. and Enfield, 1957; Zoellner et al., 1963). Heritability estimates for loin eye area varied from 0.44 to 0.79 as reported by Fredeen (1953), Depape (1954), Craft (1958), Enfield and Whatley, Jr. (1961), Jensen, Craig and Robison (1967), Omtvedt (1968) and Arganosa, Omtvedt and Walters (1969). The demand for more heavily muscled hogs and carcasses and the relatively high heritability estimates for loin eye area and backfat thickness encouraged research aimed at reducing backfat and increasing loin eye area. Jensen et al. (1967) and Arganosa et al. (1969) reported negative genetic correlations of -0.06 and -0.22 between backfat thickness and loin eye area. These studies indicated that selection against backfat thickness and / or for loin eye area should be slightly effective in reducing carcass backfat and increasing loin eye area. Dillard, Robison and Legates (1962), Hetzer and Harvey (1967), Gray *et al*. (1968) and Berruecos, Dillard and Robison (1970) reported selection was effective in reducing backfat thickness.

The purposes of this study were: (1) to develop a well-musched line of Durocs by index selection based on thinner backfat and larger loin eye area, and to maintain a control line by random selection from the same base population, (2) to investigate correlated response in production traits, carcass proportions and meat quality and (3) to determine if an increase in muscling results in undesirable effects such as PSS and PSE.

CHAPTER II

REVIEW OF LITERATURE

Many swine selection experiments were conducted during the last three decades. Conformation and litter size were the main traits for which selection was practiced. Selection for litter size was less effective since heritability of litter size is relatively small compared to heritability of conformation.

Laben and Whatley, Jr. (1947) selected for heavier 180-day weight in a Duroc inbred line and reported a decrease of 15.4 kg after five generations of selection. Litter size at weaning decreased from 6.7 pigs in the first generation, to 6.0 pigs in the fifth generation. In the sixth generation, weaned litter size was only 4.3 pigs (only 6 litters were farrowed instead of an average of about 24 litters in each of the first five generations) despite selection from litters 1.2 pigs larger than average. However, Damon and Winters (1955) reported that selection was effective in bringing about a substantial increase in the number of pigs farrowed and average weaning weights, after six years of selection for factors of performance in the Chester White and Duroc swine herds.

Hetzer, Zeller and Hankins (1956) found selection for high and low fatness was effective in Duroc and Yorkshire pigs. Zeller and Hetzer (1960) later reported that after five generations of selection in the Durocs for backfat thickness at 79.55 kg live weight average thickness increased to 5.18 cm or 38 percent above the 3.78 cm in the foundation stock. Backfat thickness decreased about 16 percent to

3.23 cm in the low fat line. In the fat Yorkshire line, backfat thickness increased from 3.20 cm in the foundation population to 3.63 cm in the third generation. The decline in backfat thickness was six percent to 3.00 cm in the low fat Yorkshires. Hetzer and Harvey (1967) reported that after 10 generations of selection, the high and low fat Duroc lines differed by 2.6 cm or 68 percent of the initial mean. Corresponding difference between the Yorkshire lines, after eight generations of selection, was 1.4 cm or 44 percent of the initial mean. Through three additional generations backfat thickness in the 13th generation, high and low-fat Duroc pigs averaged 6.0 and 2.5 cm, aud in the 11th generation high and low-fat Yorkshire pigs, the averages were 4.5 and 2.2 cm. Pigs raised concurrently in control lines averaged 3.7 and 3.0 cm, respectively, in these same generations. (Hetzer and Miller, 1970).

Selection was effective in reducing backfat thickness in a study reported by Zoellner et al. (1963) for the first two years of selection for thinner backfat in swine. Effective selection differentials for backfat were -3.70 mm for the spring and -4.50 mm for the fall of 1959. Realized response from selection for thinner backfat was -3.28 mm and -2.80 mm for spring and fall pigs, respectively. Average daily gain appeared to decrease as backfat thickness increased, but sow productivity was not altered.

Gray et al. (1968) reported that five generations of selection for less backfat thickness to reduce it about 20 percent in Poland China pigs. Backfat probe measurements were made at a live weight of 79.2 ± 2.5 kg. Berruecos et al. (1970) reported selection reduced backfat 0.065 cm per generation, when adjusted to 63.6 kg weight. Correlated responses indicated a decline in litter size and individual weights as backfat thickness decreased.

Jensen et al. (1967) reported that selection for lower backfat thickness, and / or increased areas of loin eye and percent lean cuts yielded meat with a lower water-holding capacity, less intra-muscular fat, higher shear values and lower taste panel scores for juiciness and flavor.

Arganosa et al. (1969) reported that genetic correlations between carcass backfat and percent lean cuts, backfat and loin eye area, backfat and marbling, backfat and color, and backfat and firmness were -0.58, -0.22, -0.56, -0.05 and -0.16, respectively. The above genetic correlations indicate that selection for less backfat should increase lean cuts and marbling without significantly affecting loin eye area, color aud firmness. They also reported that genetic correlations between loin eye area and percent lean cuts, loin eye area and marbling, loin eye area and firmness, and loin eye area and color were 0.77, -0.01, -0.39 and -0.73, respectively. Selection for loin eye area should increase lean cuts and decrease color without significantly affecting marbling and firmness.

CHAPTER III

MATERIALS AND METHODS

Experimental Animals

Pigs in the base population of purebred Durocs were farrowed in May, 1971. Twenty boar pigs were randomly selected in July, 1971, at which time the remaining male pigs were castrated. The select line was formed by using the highest indexing 20 gilts and four boars from the 20 boars based on an index in which maximum loin eye area and minimum backfat thickness, estimated by the An / Scan, adjusted to 100 kg live weight received equal emphasis. The control line was formed by using four randomly chosen boars (from the group of 20 boars that were randomly chosen in July at the age of ten weeks) to breed 20 randomly chosen gilts.

One restriction was that the least desirable animals because of obvious structural unsoundnesses (up to 20 percent) would not be considered as potential breeding animals.

Breeding animals were farrowed in May, produced litters the following May and were replaced after producing one litter causing generation interval to be one year. Full-sib and half-sib matings were avoided to minimize inbreeding.

When available three barrows from each litter were slaughtered in the meat laboratory. Pigs were self-fed in groups of 20 to 28 in outside pens (15 m by 30 m) and rations were standardized from year to year. Backfat thickness and loin eye area measurements on the live animal were made from the ultrasonic scanogram resulting from the use of a Polaroid Land camera.

TABLE 1. SUMMARY OF THE NUMBER OF EXPERIMENTAL ANIMALS INCLUDED IN THE STUDY.

Item	Base pop'n (1971)	Select line('72)	Control line('72)	Total
No. boars	6	4	4	14
No. gilts	32	20	20	72
No. litters farrowed	25	9	14	48
No. animals born alive	230	78	113	421
No. animals at 14 days	168	59	92	319
No. animals at 28 days	163	57	86	306
No. barrows slaughtered	51	12	27	90

A total of 72 gilts in the base population (1971) and the two lines of 1972 were bred by 14 boars from their respective groups as shown in table 1. Only 48 gilts farrowed and 421 pigs were born alive during the two generations. Birth weights were available for 421 pigs, but, 14-day and 28-day weights were obtained for only 319 and 306 pigs since some died during these two intervals. A total of 90 barrows were slaughtered and detail carcass data were collected.

Live animal backfat thickness was estimated at three locations, shoulder above the elbow, center of back at last rib and hip above the stifle joint, about 1.5 inches from the midline. Averages of the three measurements were adjusted on a 0.028 cm per kg basis to a 100 kg live weight. Live animal loin eye area was estimated at the 10th rib and adjusted to a 100 kg live weight. The adjustment was 0.213 cm^2 of loin eye area per kg of live weight. Adjusted age to 100 kg live weight was obtained by adjusting age on a 0.91 kg per day basis.

Carcass backfat thickness (that used for barrows) was the average of six measurements taken on the midline of both sides of the chilled carcass at the level of the first rib, last rib and last lumbar vertebrae. Carcass loin eye area (for barrows) at the 10th rib was traced and measured with a planimeter. Carcass length was the distance from the anterior edge of the aitch bone to the forward edge of the first rib immediately ventral to the vertebrae. Percent lean cuts was the sum of the weights of closely trimmed hams, loins and full shoulders (picnic plus Boston but) divided by chilled carcass weight. Percent primal cuts was obtained by adding the green belly weight to the weight of the lean cuts and dividing by the chilled carcass weight. Color, marbling and firmness scores were obtained for the longissimus dorsi muscle at the 10th rib and ham muscle. Color and firmness were evaluated on the basis of the Wisconsin standard scoring system (Anonymous, 1963). A score of one indicated low and a score of five represented high quality. Marbling scores ranged from one (devoid -) to 36 (extremely abundant +) (After U.S.D.A. marbling scores for beef).

Statistical Methods

The statistical technique used was that for the mixed model as reported by Harvey (1972). Lines and sexes were considered as fixed effects, while sires, dams and individuals were random effects. The base population of 1971, the select line of 1972 and the control line of 1972 represent lines 1, 2, and 3, respectively. The statistical model used in this experiment was,

$$Y_{ijklm} = u + a_i + b_{ij} + c_{ijk} + F_l + e_{ijklm}$$

Where, u = overall mean.

a_i = line effects. (fixed)

b_{ij} = sires within lines. (random)

c_{ijk} = dams within sires within lines. (random)

F_l = sex effects. (fixed)

e_{ijklm} = random errors.

The least squares analysis of variance (ANOV) scheme used in this study is presented in table 2.

Heritability and genetic, phenotypic and environmental correlations estimated from variance and covariance components were calculated using Harvey's least squares mixed model and computing program. Heritability was estimated from full-sib, and paternal half-sib correlations. Genetic correlations estimated from full-sib correlations are presented with standard errors.

TABLE 2. FORM OF LEAST SQUARES ANALYSIS OF VARIANCE.

Source	df	Variance components and coefficients
Line (fixed)	l-1	
Sire / Line	s-1	$E + k_2D + K_3S$
Dam / Sire / Line	d-1	$E + k_1D$
Sex (fixed)	f-1	
Error	T-d-f+1	E

l = Number of lines.

s = Number of sires.

d = Number of dams.

f = Number os sexes.

T = Total number of animals.

E = Variance due to differences among full-sibs.

D = Variance due to differences among dams.

S = Variance due to differences among sires.

$$k_1 = \frac{1}{d-s}(T - \sum_i \sum_j \frac{1}{n_{ij}} {}_k n^2_{ijk})$$

$$k_2 = \frac{1}{s-1}(\sum_i \sum_j \frac{1}{n_{ij}} {}_k n^2_{ijk} - \frac{1}{T} \sum\sum\sum_{ijk} n^2_{ijk})$$

$$k_3 = \frac{1}{s-1}(T - \frac{\sum\sum_{ij} n^2_{ij}}{T})$$

CHAPTER IV

EFFECT OF SELECTION ON PERFORMANCE TRAITS

Line Differences

Analyses of variance for line differences in live animal performance are presented in tables 3 and 4. Line differences were not significant for weight nor litter size at different ages, nor age, loin eye area and backfat thickness adjusted to 100 kg live weight. Further comparisons of line differences for performance traits are presented in table 5. A significant line difference ($P<.10$) was found between the base population in 1971 and the control line of 1972 for 14-day weights. The results might be due to year effects, since the control line of 1972 theoretically should have represented a continuation of the base population of 1971. Significant differences ($P<.10$) were also found between the base population of 1971 and the select line of 1972 for adjusted loin eye area and adjusted age to 100 kg live weight. The results showed that pigs in the select line in 1972 needed more time (5.04 days) to reach 100 kg and had smaller loin eye areas (0.99 cm^2) than those in the base population (table 5).

Sex Differences

Sex differences were highly significant ($P<.01$) for birth weight, but were nonsignificant in 14 and 28-day weights (table 3). Further comparisons showed that boars were 0.06 kg heavier ($P<.05$) than gilts

TABLE 3. LEAST SQUARES ANALYSES OF VARIANCE FOR WEIGHT AND LITTER SIZE AT DIFFERENT AGES.

	Birth weight		14-day weight		28-day weight		Litter size at birth		Litter size at 28-day	
Source	df	M.S.	df	M.S.	df	M.S.	df	M.S.	df	M.S.
Line	2	0.13	2	3.51	2	0.88	2	24.06	2	1.51
S / L	11	0.56	11	1.44	11	7.60	11	48.34	11	26.23
D / S / L	34	0.37**	31	1.72**	31	6.69**	34	37.57	31	30.34
Sex	1	0.37**	1	0.85	1	2.20	1	-----	1	-----
Error	372	0.05	273	0.36	260	1.29	372	-----	260	-----

*P<.05 **P<.01

M.S. = Mean Squares

TABLE 4. LEAST SQUARES ANALYSES OF VARIANCE FOR AGE, LOIN EYE AREA AND BACKFAT THICKNESS ADJUSTED TO 100 KG LIVE WEIGHT.

		Mean Squares		
Source	df	Adjusted age	Adjusted LEA	Adjusted BF
Line	2	485.04	20.33	0.26
S / L	11	285.13	11.31	0.36*
D / S / L	32	204.49**	15.42**	0.15*
Sex	2	1649.27**	235.69**	27.02**
Error	198	96.23	7.83	0.10

*P<.05 **P<.01

LEA = Loin eye area

BF = Backfat thickness

TABLE 5. COMPARISONS OF GENERATION AND LINE DIFFERENCES FOR WEIGHT AND LITTER SIZE AT DIFFERENT AGES, ADJUSTED AGE, ADJUSTED LOIN EYE AREA, AND ADJUSTED BACKFAT THICKNESS.

Item	Birth weight, kg	14-day weight, kg	28-day weight, kg	Litter size at birth, no.	Litter size at 28 days, no.	Adj. Age, day	Adj. LEA, cm^2	Adj. BF, cm
Base pop'n (B)	1.36	3.60	5.83	9.72	7.56	185.78	33.6	2.85
No. obs.	230	168	163	230	163	129	129	129
Select line (S)	1.42	3.40	5.72	9.15	7.82	190.82	32.61	2.79
No. obs.	78	59	57	78	57	52	52	52
Control line (C)	1.35	3.26	5.66	8.98	7.61	188.26	33.00	2.89
No. obs.	113	92	86	113	86	65	65	65
Difference (C-B)	-0.01	-0.34^{+}	-0.17	-0.74	0.05	2.48	-0.60	0.04
Difference (S-C)	0.07	0.14	0.06	0.17	0.21	2.56	-0.39	-0.10
Difference (S-B)	0.06	-0.20	-0.11	-0.57	0.26	5.04^{+}	-0.99^{+}	-0.06

$^{+}P < .10$

TABLE 6. COMPARISONS OF SEX DIFFERENCES IN WEIGHT AT DIFFERENT AGES.

Item	Female (F)		Male (M)		
	No.	Mean±S.E.	No.	Mean±S.E.	M-F
Birth weight, kg	205	1.34±0.04	216	1.40±0.04	0.06**
14-day weight, kg	150	3.36±0.09	169	3.48±0.09	0.12⁺
28-day weight, kg	146	5.64±0.19	160	5.83±0.19	0.19

⁺P<.10 **P<.01

TABLE 7. COMPARISONS OF SEX DIFFERENCES IN AGE, LOIN EYE AREA AND BACKFAT THICKNESS ADJUSTED TO 100 KG LIVE WEIGHT.

Item	No.	Adjusted age day	Adjusted LEA cm^2	Adjusted BF cm
Gilt(Gi)	129	189.39±1.53	34.91±0.38	2.56±0.05
Boar(Bo)	52	181.42±2.05	32.77±0.54	2.39±0.07
Barrow(Ba)	65	194.40±1.63	31.53±0.41	3.61±0.06
Gi-Bo	---	7.97**	2.14**	0.17**
Gi-Ba	---	-5.01**	3.38**	-1.05**
Bo-Ba	---	-12.98**	1.24*	-1.22**

*P<.05 **P<.01

at birth, 0.12 kg heavier ($P<.10$) than gilts at 14 days (table 6). Although no significant sex difference was found for 28-day weight, the results showed that boars were 0.19 kg heavier than gilts (table 6). These results agreed with those reported by Craig, Norton and Terril (1956) in which boars were significantly heavier than gilts by about five percent at birth and three percent at other ages. Bereskin, Shelby and Cox (1973) also reported that males were 0.03 kg heavier than females at birth ($P<.01$). The heavier boars at birth may be explained by the fact that the male fetus has a higher growth competence before birth than females (Hafez, 1968).

Least squares analyses of variance shown in table 4 reveal a highly significant sex difference ($P<.01$) for age, loin eye area and backfat thickness all adjusted to 100 kg live weight. Further comparisons of these three traits are shown in table 7. Differences among gilts, boars and barrows for each of these traits were highly significant ($P<.01$), except the significant difference ($P<.05$) in adjusted loin eye areas for boars and barrows. Boars reached 100 kg live weight about eight days earlier than gilts, and gilts reached the weight about five days earlier than barrows. The results are in agreement with those reported by Craig et al. (1956), Cox (1963) and Zoellner et al. (1963) and Berruecos et al. (1970) in which they found heavier final weights for boars. Hetzer and Miller (1972) reported boars and barrows grew faster than gilts. In this study boars had 0.17 cm less backfat than gilts and gilts had 1.05 cm less backfat than barrows. Similar results were also reported by Hetzer and Harvey (1967) and Berruecos et al. (1970) in which they found boars had 0.20 and 0.23 cm less backfat than gilts and gilts had 0.20 and 0.30 cm less than barrows, respectively. Hetzer and Miller (1972) reported that these sex differences in backfat thickness generally agreed with their previous report (Hetzer and Harvey, 1967). For loin eye area adjusted to 100 kg live weight in this study, gilts had 2.14 cm^2 larger loin eye areas than boars and boars had 1.24 cm^2 larger loin eye areas than barrows. No previous report was available to compare with these results. In brief, boars reached 100 kg at the earliest age and had the least backfat thickness, but were second to gilts in loin eye area. Contrarily, barrows were slowest reaching 100 kg live weight, had the thickest backfat and the smallest loin eye areas.

Sire and Dam Differences

Tables 3 and 4 show sire and dam differences for all performance traits. Sire effects were significant ($P<.05$) for adjusted backfat thickness but not for birth weight, 14-day and 28-day weights, or adjusted age and adjusted loin eye area. However, highly significant ($P<.01$) dam differences were found for birth weight, 14 and 28-day weights, adjusted age and loin eye area. Dam differences were also significant ($P<.05$) for backfat thickness. The highly significant dam differences for weight at birth, 14 and 28-day age might be influenced both by prenatal and postnatal direct maternal effects (Cox and Willham, 1962; Ahlschwede and Robison, 1971). The highly significant dam differences for adjusted age, adjusted loin eye area and adjusted backfat thickness may have been influenced by what Dickerson and Grimes (1947) called transmitted maternal effect, or some residual effects from prenatal and postnatal maternal effects such as milk production.

Heritability Estimates

Technique using selection response to estimate realized heritability was discussed by Falconer (1960). The procedure involves obtaining the mean differences between the base population and the control and select lines of 1972 for each trait plotted against the selection differentials. The selection differentials were estimated by substracting the average of the entire population from the selected animals in their respective lines. In the select line, backfat thickness was decreased 0.06 cm after one generation of selection. The selection differential was 0.69 cm in the same line, the value of 0.09 was obtained as the realized heritability. Realized heritability of 0.09 obtained for backfat thickness was relatively low when compared with the reports from Zoellner et al. (1963), (0.83), Cox (1964), (0.25), Hetzer and Harvey (1967), (0.46), and Gray et al. (1968), (0.32), and Berruecos et al. (1970), (0.27). Reported results indicated that appreciable reduction in backfat thickness could be obtained by the selection procedure. The samll size of the control line in this study allowed a selection differential (decrease of 0.39 cm) by chance, which resulted in a small increase (0.04 cm) in backfat thickness in their progeny when compared to the base population.

The selection differential for loin eye area in the select line was 3.44 cm^2. A decrease of 0.99 cm^2 resulted after one generation of selection. Thus, the value of -0.29 for the estimate of realized heritability was obtained. The realized heritability estimates of -0.39 for loin eye area in the control line was also obtained by the same method. The negative realized heritabilities for both select and control lines might be due to small sampling size involved.

Estimates of heritability for performance traits obtained from Harvey's least squares mixed model are listed in table 8. Estimates from full-sib and paternal half-sib correlations for birth weight were 0.95±0.15 and 0.25±0.15 respectively. The value obtained from the paternal half-sib correlation (0.25±0.15) was close to the 0.21±0.15 reported by Berruecos _et al_. (1970), but was relatively higher than the 0.05 reported by Craig _et al_. (1956). The value of 0.95±0.15 estimated from the full-sib correlation most likely resulted from extremely large sampling errors. Since sire variation was relatively small compared with dam variation, extremely high values of heritability were obtained when the dam component was included, such as from full-sib correlation. Heritability estimates for 14 aud 28-day weights from paternal half-sib correlation were -0.15±0.02 and 0.03±0.09, respectively. Heritability values of 0.66±0.15 for 14-day weight, and 0.79±0.16 for 28-day weight were estimated from full-sib correlations. No comparable reports of heritability estimates for 14 and 28-day weights are available, but the value of 0.03±0.09 for 28-day weight was close to the report from Berruecos _et al_. (1970) in which they obtained 0.01±0.03 for weaning weight.

Heritability estimates for litter size at birth and 28 days were calculated from Harvey's least squares mixed model and also by the method suggested by Becker (1968). The 0.26±0.15 for litter size at birth estimated by Harvey's program agreed fairly well with the value of 0.30±1.56 from Becker's method. The values were relatively higher than reports from Lush and Molln (1942), Boylan, Rempel and Comstock (1961), Berruecos *et al.* (1970) and Revelle and Robison (1973), in which they obtained 0.17, 0.13, -0.17 and 0.03, respectively. However, they were smaller than 0.54 reported by Shelby (1952) for litter size at birth. The -0.34±0.06 and -0.48±1.11 for litter size at 28 days were higher than the -0.05±0.16 reported by Berruecos *et al.* (1970), for litter size at weaning. No explanation can be made for negative estimates of heritability for this trait except that of sampling errors.

Heritabilities for adjusted age at 100 kg live weight estimated from full-sib and paternal half-sib correlations were 0.42±0.14 and 0.12±0.15 (table 8), respectively. Although no report of heritability estimates for this trait exists in the literature, the values obtained in this study indicate this trait is moderately heritable. Heritabilities for adjusted backfat thickness estimated by the two different methods were 0.37±0.14 and 0.40±0.24, respectively. These estimates were higher than the realized heritability (0.09) in this study. However, the results agreed fairly well with those of Berruecos *et al.* (1970) in which they obtained 0.38 and 0.27 for adjusted backfat thickness to 63.6 kg constant weight. Heritability estimates for loin eye area

TABLE 8. HERITABILITY ESTIMATES FOR PERFORMANCE TRAITS.

	Full-sib	Paternal half-sib
	$h^2 \pm$ S.E.	$h^2 \pm$ S.E.
Birth weight	0.95±0.15	0.25±0.15
14-day weight	0.66±0.15	-0.15±0.02
28-day weight	0.79±0.16	0.03±0.09
Litter size at birth[a]	2.00±0.00	0.26±0.15
Litter size at birth[b]	---------	0.30±1.56[c]
Litter size at 28 days[a]	2.00±0.00	-0.34±0.06
Litter size at 28 days[b]	---------	-0.48±1.11[c]
Adjusted age at 100 kg	0.42±0.14	0.12±0.15
Adj. loin eye area	0.26±0.12	-0.15±0.05
Adj. backfat thickness	0.37±0.14	0.40±0.24

[a] Litter sizes for individual pigs were obtained from their respective dams.

[b] Calculated directly from sire components.

[c] Confidence limits calculated by following the method suggested by Becker (1968).

from the two different methods were not consistent. The value of -0.15 ± 0.05 from the paternal half-sib correlation was in close agreement with the realized heritability value (-0.29) in this study.

Genetic, Phenotypic and Environmental Correlations

Correlation coefficients among weights and litter sizes at different ages are shown in table 9. Since other references containing these correlations were not found, they cannot be compared with previous results. Relatively high positive genetic and phenotypic correlations existed among birth weight, 14 and 28-day weights (0.71 and 0.65; 0.59 and 0.53; 0.78 and 0.75), although a large negative environmental correlation (-0.84) was calculated between birth weight and 14-day weight. The large genetic correlations among weights at progressive periods suggested that the same genes are largely responsible for weight gains made during different periods of development. Small negative genetic, phenotypic and environmental correlations were obtained among weights at birth, 14 days, 28 days and litter size at birth and 28 days. An exception was the relationship between weight at 28 days and litter size at 28 days where the correlation was near zero.

Correlation coefficients among adjusted age, adjusted loin eye area and adjusted backfat thickness are shown in table 10. Positive genetic and phenotypic correlations (0.49 and 0.21) existed between adjusted age and adjusted loin eye area, but the environmental correlation between the two traits was only 0.06. The results suggest that slower growth rate to 100 kg live weight was associated with an

TABLE 9. GENETIC, PHENOTYPIC AND ENVIRONMENTAL CORRELATIONS BETWEEN WEIGHT AND LITTER SIZE AT DIFFERENT AGES.

Item	14-day weight	28-day weight	Litter size at birth	Litter size at 28 days
Birth weight				
genetic[a]	0.71±0.13	0.59±0.16	-0.12±0.22	-0.14±0.23
phenotypic	0.65	0.53	-0.08	-0.10
environmental[a]	-0.84	0.03	-0.37	0.79
14-day weight				
genetic[a]	---------	0.78±0.10	-0.22±0.23	-0.03±0.24
phenotypic	---------	0.75	-0.13	-0.01
environmental[a]	---------	0.68	-0.25	-0.04
28-day weight				
genetic[a]	---------	---------	-0.22±0.23	0.04±0.24
phenotypic	---------	---------	-0.13	0.03
environmental[a]	---------	---------	-0.32	0.04
Litter size at birth				
genetic[a]	---------	---------	----------	0.54±0.15
phenotypic	---------	---------	----------	0.55
environmental[a]	---------	---------	----------	-0.54

[a]Estimates are from full-sib correlations.

increase in loin eye area. However, negative genetic and phenotypic correlations were calculated between adjusted age to 100 kg and backfat thickness, although the environmental correlation between these two traits was essentially zero. The results suggest that a lower rate of gain to 100 kg was associated with a decrease in backfat thickness. The result was in close agreement with that reported by Hazel and Kline (1952) who found a correlation coefficient of -0.50 between these two traits. The results also suggest the possibility that the same genes are responsible for the two traits but are influencing them in opposite directions. Multiple correlations among adjusted age, adjusted loin eye area and adjusted backfat thickness indicated that selection for larger loin eye area and / or thinner backfat thickness would increase the length of time for an animal to reach 100 kg live weight.

TABLE 10. GENETIC, PHENOTYPIC AND ENVIRONMENTAL CORRELATIONS AMONG AGE, LOIN EYE AREA AND BACKFAT THICKNESS ADJUSTED TO 100 KG LIVE WEIGHT.

Item	Adjusted loin eye area	Adjusted back-fat thickness
Adjusted age		
genetic[a]	0.49±0.30	-0.21±0.32
phenotypic	0.21	-0.07
environmental[a]	0.06	0.02
Adjusted loin eye area		
genetic[a]	---------	-0.71±0.35
phenotypic	---------	-0.25
environmental[a]	---------	-0.05

[a] Estimates are from full-sib correlations.

CHAPTER V

EFFECT OF SELECTION ON CARCASS MERIT

Line Differences

Least squares analyses of variance for carcass traits and quality scores are shown in tables 11 and 12. Significant differences among lines ($P<.05$) existed for ham color (table 12) but not for other carcass traits. Tests of least significant differences showed significant differences for carcass length, ham color and ham firmness as shown in tables 13 and 14. Carcass length for control line barrows in 1972 was significantly ($P<.05$) longer than for base population barrows in 1971 (table 13). The results suggest that environment could have favored carcass length in 1972. Ham color for the select line in 1972 was significantly ($P<.05$) darker than that for the control line of the same year (table 14). This indicates the possibility that selection for more lean and less fat would increase ham color. However, a report by Jensen *et al.* (1967) indicated that selection for thinner backfat would have an undesirable effect on the structure and color of the muscle. Table 14 also shows that ham color in the control line of 1972 was significantly ($P<.10$) darker than that in the base population. The simplest and the most likely explanation for the result would be sampling errors or a measuring technique which favored desirable ham color in 1972. Hams produced by barrows in the select line were firmer ($P<.10$) than those from the control line in 1972.

Sire and Dam Differences

Significant sire differences were found in percent lean cuts (table 11). However, sire differences were not significant for carcass backfat thickness, loin eye area, percent lean cuts and percent primal cuts. Sires did not significantly affect loin and ham color, marbling or firmnesses (table 12). Significant dam differences ($P<.05$) existed for carcass length (table 11) and ham marbling (table 12), but dam effects did not significantly affect other carcass traits, including quality scores. The result possibly suggests that direct maternal effect and / or transmitted maternal effect influenced these two traits.

TABLE 11. LEAST SQUARES ANALYSES OF VARIANCE FOR CARCASS LENGTH, BACKFAT THICKNESS, LOIN EYE AREA AND PERCENT LEAN AND PRIMAL CUTS.

		Mean Squares				
Source	df	Carcass backfat	Carcass LEA	Carcass length	% lean cuts	% primal cuts
Line	2	0.17	5.71	17.84	14.16	11.27
S / L	10	0.20	20.75	5.31	10.78*	6.19
D / S / L	26	0.17	12.40[a]	4.24*	4.69	3.35
Error	51	0.13	7.04[b]	1.85	5.78	4.62

*$P<.05$

[a]25 degrees of freedom.

[b]47 degrees of freedom.

TABLE 12. LEAST SQUARES ANALYSES OF VARIANCE FOR LOIN AND HAM QUALITY SCORES.

		Mean Squares					
		Color		Marbling		Firmness	
Source	df	Loin	Ham	Loin	Ham	Loin	Ham
Line	2	0.43	1.09*	38.60	76.31	0.57	1.04
S / L	10	0.50	0.28	32.93	31.83	0.35	0.43
D / S / L	26	0.33	0.24	41.49	24.02*	0.37	0.27
Error	51	0.30	0.21	40.27	13.36	0.26	0.17

*P<.05

TABLE 13. COMPARISONS OF GENERATION AND LINE DIFFERENCES FOR BACKFAT THICKNESS, LOIN EYE AREA, PERCENT LEAN AND PRIMAL CUTS AND CARCASS LENGTH.

Item	Carcass BF, cm	Carcass length, cm	Lean cuts, %	Primal cuts, %	Carcass LEA, cm^2
Base pop'n (1971)	3.64±0.06	76.43±0.32	56.65±0.34	72.64±0.30	31.71±0.55
Select line (1972)	3.54±0.12	77.61±0.65	58.32±0.71	74.07±0.63	32.79±1.03
Control line (1972)	3.51±0.08	77.74±0.34	57.24±0.49	72.53±0.43	32.02±0.67
Difference (C-B)	-0.13	1.31 *	0.59	-0.12	0.31
Difference (S-C)	0.04	-0.13	1.07	1.54	0.78
Difference (S-B)	-0.10	1.18	1.66	1.42	1.08

*P<.05

TABLE 14. COMPARISONS OF GENERATION AND LINE DIFFERENCES FOR LOIN AND HAM QUALITY SCORES.

Item	Loin Color	Ham Color	Loin marbling	Ham marbling	Loin firmness	Ham firmness
Base pop'n (B) (1971)	3.21±0.08	3.28±0.09	22.3±0.1	15.8±0.7	3.42±0.09	3.10±0.08
Select line (S) (1972)	3.33±0.17	3.50±0.14	24.0±0.2	14.8±0.2	3.46±0.18	3.29±0.16
Control line (C) (1972)	3.04±1.11	3.02±0.09	21.0±0.1	12.9±0.1	3.19±0.11	2.83±0.09
Difference (C-B)	-0.17	-0.26+	-1.30	-0.80	-0.24	-0.27
Difference (S-C)	0.30	0.48*	3.00	1.90	0.27	0.46+
Difference (S-B)	0.13	0.23	-1.80	-1.10	0.04	0.19

+P<.10 *P<.05

Heritability Estimates

Heritability estimates for carcass proportions and carcass quality scores are shown in table 15. Estimate of 0.27±0.25 from the full-sib correlation for carcass backfat thickness closely agreed with reports by Lush (1936), Johansson and Korkman (1950), Hetzer and Zeller (1956), Zoellner *et al.* (1963), Gray *et al.* (1968) and Berruecos *et al.* (1970). The lower value of 0.13±0.37 estimated from the paternal half-sib correlation agreed quite well with the 0.12 estimated by Blunn and Baker

(1947). The 0.13 value was also similar to the realized heritability (0.09) in this study.

Heritability estimates for loin eye area of 0.70±0.27 and 0.49±0.50 were obtained by the full-sib and paternal half-sib correlation methods, respectively. The value of 0.49±0.50 estimated from the paternal half-sib correlation was the same as the 0.49 reported by Smith and Ross (1965), and similar to the 0.47 reported by Jensen et al. (1967). The 0.70±0.27 estimated from the full-sib correlation was close to the 0.66 reported by Fredeen (1953), and the 0.79 reported by Enfield and Whatley, Jr. (1961). Evidence from this study indicates that additive genetic variance in loin eye area makes a major contribution to the total phenotypic variance.

Heritability of carcass length estimated from the full-sib and paternal half-sib correlations were 0.79±0.26 and 0.20±0.39, respectively. These two values fit into a wide range in results (Arganosa et al., 1969) in which they reported that 20 estimates in the literature averaged 0.52 (ranged from 0.20 to 0.87). Dickerson (1947) reported heritability of carcass length as near 0.75 in swine. Heritability estimates of 0.10±0.23 and 0.51±0.48 for percent lean cuts were estimated from full-sib and paternal half-sib correlations, respectively. The value of 0.51±0.48 was close to the reports from Jensen et al. (1967), (0.40); Omtvedt (1968), (0.62); and Arganosa et al. (1969), (0.68). Craft (1958) also calculated, from a number of published and unpublished reports, an average heritability estimate of 0.31 for percent lean cuts. The range was from 0.14 to 0.76. In this study heritability estimates

TABLE 15. HERITABILITY ESTIMATES FOR CARCASS TRAITS.

Item	Full-sib	Paternal half-sib
	$h^2 \pm S.E.$	$h^2 \pm S.E.$
Carcass loin eye area	0.70±0.27	0.49±0.50
Carcass backfat	0.27±0.25	0.13±0.37
Carcass length	0.79±0.26	0.20±0.39
Percent lean cuts	0.10±0.23	0.51±0.48
Percent primal cuts	-0.15±0.20	0.23±0.40
Loin color	0.26±0.25	0.31±0.43
Ham color	0.15±0.24	0.11±0.36
Loin marbling	-0.04±0.21	-0.14±0.28
Ham marbling	0.61±0.26	0.24±0.41
Loin firmness	0.28±0.25	-0.05±0.31
Ham firmness	0.58±0.26	0.42±0.46

of -0.15±0.20, 0.23±0.40 were obtained for percent primal cuts from full-sib and paternal half-sib correlations, respectively. Negative estimates of heritability were due to negative dam components which most likely resulted from sampling errors.

Jensen et al. (1967) reported an estimate of 0.19±0.14 for loin marbling. The negative estimates of -0.40±0.21 and -0.14±0.28 for loin marbling were obtained from full-sib and paternal half-sib correlations, respectively. Heritability estimates of 0.61±0.26 and 0.24 ±0.41 indicate ham marbling is moderately to highly heritable, although no comparable report was available in the literature.

Heritabilities of 0.26±0.25 and 0.31±0.43 for loin color estimated by the two different methods were in close agreement with the 0.28 reported by Jensen et al. (1967). These results also support the conclusion of Jonsson (1965), Pease and Smith (1965) and Arganosa et al. (1969), that color is moderately heritable and selection for meat color should lead to a genetic change in the color score. Heritability estimates of 0.15±0.24 and 0.11±0.36 for ham color were comparable to estimates for loin color in this study. Again, no references were available in the literature, thus a comparison of the present findings with previous findings was not possible.

Heritability estimates from the full-sib and paternal half-sib correlations were 0.28±0.25 and -0.05±0.31 for loin firmness, respectively. Again the present values were fairly close to those of Johanson and Korkman (1950), (0.40), Smith and Ross (1965), (0.41), Jensen et al. (1967), (0.21) and Omtvedt (1968), (0.30). Loin firmness appears to be moderately heritable. The two estimates of heritability for ham firmness were 0.58±0.26 and 0.42±0.46 suggesting that ham firmness is highly heritable.

Genetic, Phenotypic and Environmental Correlations

Genetic, phenotypic and environmental correlations between carcass backfat thickness, loin eye area, carcass length and percent lean cuts are presented in table 16. The unrealistic estimated genetic correlation of -1.31±1.17 between carcass loin eye area and backfat thickness was higher than the estimate of -0.45, -0.10, -0.06 and -0.22 reported by Hazel and Kline (1952), Enfield and Whatley, Jr. (1961), Jensen et al. (1967) and Arganosa et al. (1969), respectively. The value was also higher than the correlation of -0.71±0.35 between adjusted backfat thickness and adjusted loin eye area to 100 kg live weight in this study. The negative phenotypic correlation of -0.30 between carcass backfat thickness and loin eye area was consistent with estimates reported by Whiteman and Whatley, Jr. (1961). Relatively high negative correlations between carcass loin eye area and carcass backfat thickness in this study suggested that both traits are influenced by the same genes, but in opposite directions, despite the moderately positive environmental correlation between the traits. The genetic correlation of -0.59±0.52 between carcass backfat thickness and carcass length was in close agreement with the -0.62 reported by Arganosa et al. (1969), but was higher than the -0.19 reported by Enfield and Whatley, Jr. (1961). The phenotypic correlation of -0.15 between these two traits was less than the -0.36 reported by Enfield and Whatley, Jr. (1961). Genetic correlation of -0.85±2.08 between carcass backfat thickness and percent lean cuts were in close agreement with the estimates of -0.91, -0.81 and -0.58 reported by Holland and

Hazel (1958), Jensen et al. (1967), and Argauosa et al.(1969), respectively. A negative phenotypic correlation of -0.69 was obtained between these two traits, which was relatively higher than that the -0.49 reported by Jensen et al. (1967), while a large negative environmental correlation was obtained between these two traits. Positive genetic and phenotypic correlations (1.14±1.18 and 0.12) were obtained between carcass length and percent lean cuts, while the environmental correlation was -0.46. The above correlations suggested that selection for less backfat thickness should result in larger loin eye areas, longer carcasses and a slightly higher percentage of lean cuts.

TABLE 16. GENETIC, PHENOTYPIC AND ENVIRONMENTAL CORRELATIONS BETWEEN LOIN EYE AREA, BACKFAT THICKNESS, CARCASS LENGTH AND PERCENT LEAN CUTS.

Item	Loin eye area	Carcass length	Percent lean cuts
Backfat thickness			
genetic[a]	-1.31±1.17	-0.59±0.52	-0.85±2.08
phenotypic	-0.30	-0.15	-0.69
environmental[a]	0.25	0.31	-0.68
Carcass length			
genetic[a]	----------	----------	1.14±1.18
phenotypic	----------	----------	0.12
environmental[a]	----------	----------	-0.46

[a] Estimates are from full-sib correlations.

Genetic, phenotypic and environmental correlations among carcass quality scores are presented in table 17. The zero genetic correlations associated with zero standard errors between loin marbling and loin color, ham color, ham marbling, loin firmness and ham firmness resulted when the computer extracted the square root of negative values. The zero standard errors resulted from the same computer procedure. The correlation coefficients among loin color, loin marbling and loin firmness were relatively high and positive. The genetic correlation between loin color and firmness was 0.42±0.52. However, relatively large phenotypic correlations between loin color and marbling, loin color and firmness, and loin marbling and firmness were 0.60, 0.70 and 0.69, respectively. These values were higher than 0.29, 0.35 and 0.48 reported by Arganosa et al. (1969) for the same traits. Positive and large environmental correlations were also found among the above three traits (0.90, 0.80 and 0.57). Close genetic associations were found between ham color and firmness (1.00±0.14) and between ham marbling and ham firmness (1.04±0.14), but a slightly genetic relationship (0.07±0.64) was found between ham color and marbling. Genetic correlations of 0.54±0.61 and 0.71±0.31 were obtained between ham color and loin color, and ham firmness and loin firmness, respectively. Color aud firmness were closely associated in the loin and ham with a genetic correlation of 0.68±0.53 and phenotypic and environmental correlations of 0.55 and 0.53. The genetic correlation of 0.18±0.49 between loin firmness and ham marbling along with the phenotypic and environmental correlations of 0.33 and 0.49, indicated

TABLE 17. GENETIC, PHENOTYPIC AND ENVIRONMENTAL CORRELATIONS AMONG HAM AND LOIN QUALITY SCORES.

Item	Loin marbling	Loin firmness	Ham color	Ham marbling	Ham firmness
Loin color					
genetic[a]	0.0 ±0.0[b]	0.42±0.52	0.54±0.61	-0.27±0.49	0.08±0.54
phenotypic	0.60	0.70	0.55	0.26	0.43
environ.[a]	0.90	0.80	0.55	0.70	0.73
Loin marbling					
genetic[a]	---------	0.0 ±0.0[b]	0.0 ±0.0[b]	0.0 ±0.0[b]	0.0 ±0.0[b]
phenotypic	---------	0.69	0.44	0.57	0.52
environ.[a]	---------	0.57	0.57	0.56	0.46
Loin firmness					
genetic[a]	---------	---------	0.68±0.53	0.18±0.49	0.71±0.31
phenotypic	---------	---------	0.55	0.33	0.55
environ.[a]	---------	---------	0.53	0.49	0.47
Ham color					
genetic[a]	---------	---------	---------	0.07±0.64	1.00±0.14
phenotypic	---------	---------	---------	0.31	0.67
environ.[a]	---------	---------	---------	0.50	0.62
Ham marbling					
genetic[a]	---------	---------	---------	----------	1.04±0.14
phenotypic	---------	---------	---------	----------	0.55
environ.[a]	---------	---------	---------	----------	-0.17

[a]Estimates are from full-sib correlations.

[b]Undefined values have been set as zero.

these two traits were not highly correlated. Loin color aud ham marbling were negatively genetically associated. (-0.27 ± 0.49), but with positive and low phenotypic correlation and positive high environmental correlation. A genetic correlation of 0.08 ± 0.54 was found between loin color and ham firmness, but the phenotypic correlation between these two traits was 0.43 and the environmental correlation was 0.73. In summary, loin color was moderately associated with ham color and loin firmness, but was almost independent of ham firmness and was negatively associated with ham marbling.

CHAPTER VI

SUMMARY

Significant differences ($P<.10$) were found between the base population in 1971 and the control line of 1972 for 14-day weight and between the base population and the select line of 1972 for loin eye area and age adjusted to 100 kg live weight. Sex caused weight differences in favor of the boars ranging from 0.06 kg at birth to 0.19 kg at 28 days. Boars reached 100 kg at the earliest age and had the least backfat thickness, but were second to gilts in loin eye area. Contrarily, barrows were slowest reaching 100 kg live weight, had the thickest backfat and the smallest loin eye areas. Sire effects were highly significant ($P<.01$) for adjusted backfat thickness and dam differences were highly significant ($P<.01$) for birth weight, 14 and 28-day weights, adjusted age, loin eye area and backfat thickness ($P<.05$).

The low heritabilities for weight and litter size at different ages estimated from paternal half-sib correlations agreed fairly well with those reported in the literature. Extremely high values of heritability were obtained when the dam components were included, such as from full-sib, since the sire components were relatively small compared with dam components. Heritability estimates for adjusted age, loin eye area and backfat thickness indicated that these three traits are moderately to highly heritable. Relatively high positive genetic and phenotypic correlations existed among birth weight, 14 and 28-day weights. The large genetic correlations among weights at progressive periods suggested that the same genes are largely responsible for weight gains made during different periods of development. Multiple correlations among adjusted age, adjusted loin eye area and adjusted backfat thickness indicated that selection for larger loin eye area and / or thinner backfat thickness would increase the length of time for an animal to reach 100 kg live weight.

Carcass length for control line barrows in 1972 was significantly ($P<.05$) longer than for base population barrows in 1971. Hams from select line barrows in 1972 were significantly ($P<.05$) darker than those from control line barrows of the same year. Hams in the control line of 1972 were significantly ($P<.10$) darker than those in the base population. Hams produced by barrows in the select line were firmer ($P<.10$) than those from the control line in 1972. Significant sire effects were found for percent lean cuts ($P<.05$), and dam effects were significant ($P<.05$) for carcass length and ham marbling.

Heritability estimates showed that carcass loin eye area, carcass length, ham marbling and ham firmness were highly heritable, while, carcass backfat thickness, and loin color and firmness were moderately heritable. Percent lean and primal cuts, ham color, and loin marbling were lowly heritable.

The genetic, phenotypic and environmental correlations among carcass loin eye area, carcaos backfat and carcass length and percent lean cuts suggested that selection for less backfat thickness should result in larger loin eye areas, longer carcasses and a slightly higher percentage of lean cuts. Correlation coefficients among color, marbling and firmness in the loin and the ham were closely associated. Loin color was moderately associated with ham color and loin firmness, but was almost independent of ham firmness and was negatively associated with ham marbling.

LITERATURE CITED

Ahlschwede, W. T. and O. W. Robison. 1971. Prenatal and postnatal influence on growth and backfat in swine. J. Anim. Sci. 32:10.

Anonymous. February, 1963. Pork quality standards. Wisconsin Special Bulletin #9.

Arganosa, V. G., I. T. Omtvedt and L. E. Walters. 1969. Phenotypic and genotypic parameters of some carcass traits in swine. J. Anim. Sci. 28:168.

Becker, W. A. 1968. Manual of procedures in quantitative genetics. Washington State University Book Store, Pullman, Washington.

Bereskin, B., C. E. Shelby and D. F. Cox. 1973. Some factors affecting pig survival. J. Anim. Sci. 36:821.

Berruecos, J. M., E. U. Dillard and O. W. Robison. 1970. Selection for low backfat thickness in swine. J. Anim. Sci. 30:844.

Blunn, C. T. and M. L. Baker. 1947. The relation between average daily gain and some carcass measurements. J. Anim. Sci. 6:424.

Boylan, W. J., W. E. Rempel and R. E. Comstock. 1961. Heritability of litter size in swine. J. Anim. Sci. 20:566.

Cox, D. F. and R. L. Willham. 1962. Systematic fostering experiments in swine. J. Anim. Sci. 21:366.

Cox, D. F. 1963. Breed and sex effects on the relationship between weight and fatness measured at a constant age in swine. J. Anim. Sci. 22:1091.

Cox, D. F. 1964. Heritability of backfat thickness measured on the live pig at a constant age. J. Anim. Sci. 23:447.

Craft, W. A. 1958. Fifty years of progess in swine breeding. J. Anim. Sci. 17:960.

Craig, J. V., H. W. Norton and S. W. Terril. 1956. A genetic study of weight at five ages in Hampshire swine. J. Anim. Sci. 15:242.

Damon, R. A. and L. M. Winters. 1955. Selection for factors of performance in the swine herds of the Hormel Foundation. J. Anim. Sci. 14:29.

Depape, J. G. 1954. Swine carcass studies. I. Genetic variation and covariation in carcass characteristics. Ph.D. Thesis. Oklahoma State University, Stillwater, Oklahoma.

Dickerson, G. E. 1947. Composition of hog carcasses as influenced by heritable differences in rate of economy of gain. Iowa State College Research Bulletin. 354.

Dickerson, G. E. and J. C. Grimes. 1947. Effectiveness of selection for efficiency of gain in Duroc swine. J. Anim. Sci. 6:264.

Dillard, E. U., O. W. Robison and J. E. Legates. 1962. Selection for low backfat and weight ratio in swine. J. Anim. Sci. 21:971.

Enfield, F. D. and Whatley, J. A., Jr. 1961. Heritability of carcass length, carcass backfat thickness and loin eye area in swine. J. Anim. Sci. 20:631.

Falconer, D. S. 1960. Introduction to quantitative genetics. The Ronald Press Company. New York.

Fredeen, H. T. 1953. Genetic aspects of Canadian Bacon production. Department Agri. Publ. No. 889, Ottawa, Canada.

Gray, R. C., L. F. Tribble, B. N. Day and J. F. Lasley. 1968. Results of five generations of selection for low backfat thickness in swine. J. Anim. Sci. 27:118.

Hafez, E. S. E. 1968. Reproduction in farm animals. Lea and Febiger Publishing Company.

Harvey, W. R. 1972. General outline of computing procedure for six types of mixed models. Presented at NC-1 and NC-103 Annual Meeting, 1973. Oklahoma City, Oklahoma.

Hazel, L. N. and E. A. Kline. 1952. Mechanical measurement of fatness and carcass values on live hogs. J. Anim. Sci. 11:313.

Hetzer, H. O. and J. H. Zeller and O. G. Hankins. 1956. Carcass yield as related to live hog probes at various weights and locations. J. Anim. Sci. 15:256.

Hetzer, H. O. and W. R. Harvey. 1967. Selection for high and low fatness in swine. J. Anim. Sci. 26:1244.

Hetzer, H. O. and R. H. Miller. 1970. Influence of selection for high and low fatness on reproductive performance of swine. J. Anim. Sci. 30:481.

Hetzer, H. O. and R. H. Miller. 1972. Rate of growth as influenced by selection for high and low fatness in swine. J. Anim. Sci. 35:730.

Holland, L. A. and L. N. Hazel. 1958. Relationship of live measurements and carcass characteristics of swine. J. Anim. Sci. 17:825.

Jensen, P., H. B. Craig and O. W. Robison. 1967. Phenotypic and genetic associations among carcass traits of swine. J. Anim. Sci. 26:1252.

Johansson, I. and N. Korkman. 1950. A study of the variation in production traits of bacon pigs. Acta. Agri. Scand. 1:62-96.

Jonsson, P. 1965. Analysis of characters in the Danish Landrace pig with a historical introduction. 350. beretning fra forsogslaboratoriet, Kobemhavn.

Laben, R. C. and J. A. Whatley, Jr. 1947. Selection in an inbred line of Duroc Jerseys. J. Anim. Sci. 6:478.

Lush, J. L. 1936. Genetic aspects of the Danism system of progeny testing swine. Iowa State Research Bulletin. 204.

Lush, J. L. and A. E. Molln. 1942. Litter size and weight as permanent characteristics of sows. U.S.D.A. Tech. Bull. 836.

Omtvedt, K. T. 1968. The pork Industry: Problems and Progress. Some heritability characteristics and their importance in a selection program. Iowa State Press.

Pease, A. H. R. and C. Smith. 1965. A note on the heritability of muscle color in pigs. Anim. Prod. 7:273.

Revelle, T. J. and O. W. Robison. 1973. An explanation for the low heritability of litter size in swine. J. Anim. Sci. 37:668.

Shelby, C. E. 1952. Genetic aspects of the production registry program of the United Duroc Record Association. Ph.D. Thesis. Iowa State University, Ames, Iowa.

Smith, C. and Ross, G. J. S. 1965. Genetic parameters of British Landrace bacon pigs. Anim. Prod. 7:291.

Whatley, J. A., Jr. and F. D. Enfield. 1957. Heritability of carcass length, carcass backfat thickness and loin lean area in swine. J. Anim. Sci. 16:1066.

Whiteman, J. V. and J. A. Whatley, Jr. 1953. An evaluation of some swine carcass measurements. J. Anim. Sci. 12:591.

Zeller, J. H. and H. O. Hetzer. 1960. Selection for high and low fatness. U.S.D.A. Regional Swine Breeding Laboratory Record of Proceedings. PP. 61-62.

Zoellner, K. O., J. F. Lasley, L. F. Tribble and B. N. Day. 1963. Selection for thinner backfat in swine. Mo. Agr. Exp. Res. Bull. 831.

SELECTION FOR MAXIMUM LOIN EYE AREA AND MINIMUM BACKFAT THICKNESS IN DUROC SWINE

by

CHING HSONG CHANG

Diploma, Taiwan Provincial Ping-tung Institute of Agriculture, 1970

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE
ANIMAL SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1974

Pigs in the base population of purebred Durocs were farrowed in May, 1971. In July, 20 boar pigs were randomly selected and the remaining male pigs were castrated. The select line was formed by using the 20 most desirable gilts and four boars based on an index in which maximum loin eye area and minimum backfat thickness, estimated by An / Scan, adjusted to 100 kg received equal emphasis. The control line was formed by using four randomly chosen boars to breed 20 randomly chosen gilts. Twenty-five litters were farrowed in the base population, and nine and 14 litters were farrowed in the select and control line of 1972, respectively. A total of 90 barrows were slaughtered in the departmental meat laboratory, 51 were from the base population, and 12 and 27 were from the select and control line of 1972, respectively.

A significant difference ($P<.10$) was found between the base population in 1971 and the control line of 1972 for 14-day weight. Significant differences ($P<.10$) were also found between the base population of 1971 and the select line of 1972 for loin eye area and age adjusted to 100 kg live weight. Sex caused weight differences in favor of the boars ranging from 0.06 kg at birth to 0.19 kg at 28 days. Boars reached 100 kg at the earliest age and had the least backfat thickness, but were second to gilts in loin eye area. Contrarily, barrows were slowest reaching 100 kg live weight, had the thickest backfat and the smallest loin eye areas. Sire effects were highly significant ($P<.01$) for adjusted backfat thickness and dam differences were highly significant ($P<.01$) for birth weight, 14 and 28-day weights, adjusted age, loin eye area and backfat thickness ($P<.05$).

The low heritabilities for weight and litter size at different ages estimated from paternal half-sib correlations agreed fairly well with those reported in the literature. Heritability estimates for adjusted age, loin eye area and backfat thickness indicated these three traits are moderately to highly heritable. Relatively high positive genetic and phenotypic correlations existed among birth weight, 14 and 28-day weights. The large genetic correlations among weights at progressive periods suggested that the same genes are largely responsible for weight gains made during different periods of development. Multiple correlations among adjusted age, adjusted loin eye area and adjusted backfat thickness indicated that selection for larger loin eye area and / or thinner backfat thickness would increase age of the animal at 100 kg live weight.

Control line barrows in 1972 produced significantly ($P<.05$) longer carcasses than those produced by base population barrows in 1971. Hams from the select line barrows in 1972 were significantly ($P<.05$) darker than those from the control line barrows the same year. Ham color in the control line of 1972 was significantly ($P<.10$) lighter than in the base population of 1971. Hams produced by barrows in the select line were firmer ($P<.10$) than those from the control line in 1972. Sire effects were significant for percent lean cuts ($P<.05$), while, dam effects significantly ($P<.05$) influenced carcass length and ham marbling.

Heritability estimates for carcass traits showed that carcass loin eye area, carcass length, ham marbling and ham firmness were highly heritable, while, carcass backfat thickness, loin color and firmness were moderately heritable. Percent lean and primal cuts, loin and ham color, and loin marbling were lowly heritable. Selection for less backfat should result in larger loin eye areas, longer carcasses and a slightly higher percentage of lean cuts. Color and firmness in the loin and ham were closely associated. Loin color was moderately associated with ham color and loin firmness, but was almost independent of ham firmness and was negatively associated with ham marbling.