Selection for Lean Growth in Swine

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SELECTION FOR LEAN GROWTH IN SWINE[1]

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Summary

Growth rate (ADG) and backfat (BF) data were collected during five generations of selection in two lines of Gene Pool pigs (14-breed synthetic): select (S) and control (C). C were randomly selected, while mass selection was practiced in the S line with an index (I), I = 100 + 286.6 (ADG) − 39.4 (BF). S and C pigs were fed a 14% protein, corn-soybean meal diet from 42 d of age until they reached 79.4 kg. The ratio of weighted to unweighted selection differentials offers evidence that natural selection was not working against artificial selection. Weighted cumulative selection differentials (adjusted for any unintentional selection occurring in the C line) were .40 kg ADG, −.70 cm BF and 143 I units. The regressions of response (S−C) on generation number were .014 ± .002 kg ADG, −.045 ± .010 cm BF and 5.76 ± .30 I units. The realized response was 41 and 38% of the expected response for ADG and BF, respectively. Realized heritability estimate for the I was .19 ± .029. The index in retrospect indicated that other factors such as natural selection and management had little effect on the selection criteria. Index selection was effective in improving both ADG and BF.

(Key Words: Swine, Index Selection, Lean Growth.)

Introduction

Growth rate and leanness are economically important traits of swine production, and thus, both should be emphasized in a swine selection program. In swine, selection for growth rate is effective, as demonstrated by Krider et al. (1946) and Rahnefeld and Garnett (1976). Selection for low backfat has also been effective (Hetzer and Harvey, 1967; Gray et al., 1968; Berruecos et al., 1970). However, several studies (Dickerson, 1947; Zoellner et al., 1963; Edwards and Omtvedt, 1971; Robison and Berruecos, 1973; McPhee et al., 1979), have demonstrated that an undesirable genetic relationship exists between these two traits which reduces the potential for simultaneous genetic improvement in both traits.

Fredeen et al. (1976) practiced eight generations of selection for lean growth in Lacombe swine based on an index involving backfat and growth rate. Leymaster et al. (1979a) practiced four generations of selection for weight of lean cuts in Yorkshire swine. In another experiment (Vangen, 1979) eight generations of lean growth selection were based on an index involving growth rate and backfat.

The use of an index without economic weights is recommended when index traits are of equal importance (Baker, 1974). Dickerson (1978) and Tess (1981) reported that growth rate and leanness differ in their contribution to economic efficiency. If the relative economic value of growth rate and leanness differs a great deal, an index constructed on economic weights and estimates of genetic and phenotypic statistics is preferred (Lin, 1978).

The purpose of the research reported herein was to determine the effectiveness of selection for lean growth in a closed swine herd based on an index constructed from economic weights and genetic and phenotypic statistics for average daily gain and backfat.

Materials and Methods

Population. The University of Nebraska Gene Pool population was established by the introduction of 13 breeds of swine into a Hampshire female population (Zimmerman and Cunningham, 1975). After the introduction of the last breed in 1965, the 14-breed synthetic population was closed to outside introductions and maintained by random mating until the initiation of an ovulation rate experiment in 1967.

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TABLE 1. NUMBER OF BOARS AND GILTS WEIGHED AND PROBED, BY LINE AND GENERATION

Generation	Select		Control	
	Boars	Gilts	Boars	Gilts
0	63	66	69	72
1	45	59	54	44
2	61	63	50	59
3	54	56	57	63
4	61	72	55	46
5	64	67	56	69
Average	58	64	57	59

The specific percentage of each breed in the population has not been resolved.

Third generation (1971) select and control line pigs from the ovulation rate experiment were reciprocally crossed. Crossline pigs were randomly assigned within litter and sex to one of two lines (select or control) to form the base population for a lean growth experiment.

Experimental Procedure. At weaning (42 d), pigs were assigned within litter and sex to dirt lot pens. At this time pigs were fed a 14% protein diet containing corn (IFN 4-02-931), soybean meal (IFN 5-04-604), dicalcium phosphate (IFN 6-01-080), limestone (IFN 6-02-632), iodized salt (IFN 6-04-151), trace mineral premix and vitamin premix until they were removed from test at approximtely 79.4 kg (Cunningham et al., 1973). Average daily gain (ADG) was measured over the test period.

Probe backfat (BF) measurements were taken at the first rib, last rib and last lumbar vertebra at approximately 79.4 kg of body weight. Average BF was calculated from these three measurements and adjusted to 90.7 kg. The weight of 90.7 kg was selected because statistics used in index construction were based on this weight (Cunningham et al., 1973). Management limitations did not allow the pigs to be taken to a weight of 90.7 kg. During generation 0 to 3, a lean-meter[4] was used to measure BF; a scanoprobe[5] was used in generation 4 and 5. Number of boars and gilts weighed and probed by line and generation are presented in table 1.

Selection Procedure. Selection for lean growth was practiced for five generations in the select (S) line. Replacement boars and gilts in the S line were mass selected on the basis of an index (I) involving ADG over the test period and BF adjusted to 90.7 kg where I = 100 + 286.6 (ADG, kg) − 39.4 (BF, cm). The following statistics for ADG and BF were used in the index construction: standard deviation, .08 kg and .41 cm; heritability, .33 and .40, rp = −.02 and rg = −.20 (Cunningham et al., 1973). Relative economic values used in the index were 2.0 and −1.0 for ADG and BF, respectively. The control (C) line was randomly selected, with one boar chosen from each sire used the previous generation and no more than three gilts from any one sire.

Matings within lines were restricted so that inbreeding was minimized. Attempts were made to equalize the number of matings per sire, with each sire initially assigned to a maximum of three gilts. The generation interval was 1 yr. Number of sires and number of females selected and farrowing by line and generation are summarized in table 2.

Analysis of Data. Weighted selection differentials for ADG, BF and I were calculated separately for each sex in the S and C lines. Each parent was weighted by the number of offspring it produced (that completed the test), in calculating the mean parental performance. This was necessary since individual parents do not contribute equally to the next generation (Falconer, 1960). Weighted selection differentials were calculated by subtracting the respective line-sex mean from the mean parental performance. In each generation, the selection

[4]Manufactured by Duncan Electric Manufacturing Co., Lafayette, IN 47907.

[5]Manufactured by Ithaca, Inc., Ithaca, NY 14850.

TABLE 2. NUMBER OF SIRES AND NUMBER OF FEMALES SELECTED AND FARROWING BY LINE AND GENERATION

Generation	Select			Control		
	Sires	Gilts selected	Gilts farrowing	Sires	Gilts selected	Gilts farrowing
1	12	27	21	12	26	21
2	10	29	23	12	27	21
3	10	31	20	12	32	24
4	10	32	23	14	32	18
5	11	34	23	13	33	27
Average	10.6	30.6	22	12.6	30	22.2

differentials for males and females were averaged and then summed across generations to yield the cumulative selection differential. The adjusted comulative selection differential was calculated as the difference between S and C line cumulative selection differentials.

The line mean was the arithmetic average of the two sexes. Line differences (S−C) for ADG, BF and I were calculated as the difference between the S and C line for each generation. Total response (S_5-C_5 − S_0-C_0) was measured as the difference between the S and C lines adjusted for the line difference in generation 1. Regressions of line difference on generation were calculated. The standard error of the regression coefficients included drift error as described by Hill (1972).

Expected response (in ADG and BF) was calculated according to Pirchner (1969). For this calculation the values utilized were the selection differential and phenotypic statistics observed in the experiment and the genetic statistics which were used in the index construction (Cunningham et al., 1973).

Realized heritability for the index was estimated as the regression of line difference in each generation on cumulative weighted selection differential. The standard error of the realized heritability estimate also included drift error as formulated by Hill (1972).

The actual weightings in the selection index were calculated by the "index in retrospect" technique described by Dickerson et al. (1954).

Results and Discussion

Inbreeding. Average percentage inbreeding is presented by line and generation in table 3. As expected, selection of one replacement boar and a maximum of three gilts from each sire resulted in less cumulative inbreeding in line C than in line S in which mass selection was practiced. Within lines, matings were planned to minimize inbreeding. However, it was not

TABLE 3. AVERAGE PERCENTAGE INBREEDING BY LINE AND GENERATION

Generation	Select		Control	
	Litter	Dam	Litter	Dam
0	0 ± 0[a]	.24 ± .25	0 ± 0	.22 ± .22
1	0 ± 0	0 ± 0	0 ± 0	0 ± 0
2	.12 ± .04	0 ± 0	.04 ± .02	.03 ± .02
3	2.06 ± .31	.06 ± .03	0 ± 0	.03 ± .02
4	5.39 ± .53	1.79 ± .31	.94 ± .15	0 ± 0
5	5.15 ± .22	5.31 ± .52	1.49 ± .12	.89 ± .12

[a]Mean ± standard error.

TABLE 4. GENERATION MEANS BY TRAIT, SEX AND LINE

Generation	Select Boars	Select Gilts	Select Average	Control Boars	Control Gilts	Control Average
			Average daily gain, kg			
0	.65 ± .01[a]	.64 ± .01	.64 ± .01	.65 ± .01	.63 ± .01	.64 ± .01
1	.67 ± .01	.68 ± .01	.68 ± .01	.64 ± .01	.68 ± .01	.66 ± .01
2	.68 ± .02	.74 ± .01	.71 ± .01	.68 ± .01	.67 ± .01	.67 ± .01
3	.68 ± .01	.65 ± .01	.66 ± .01	.62 ± .01	.62 ± .01	.62 ± .01
4	.73 ± .01	.73 ± .01	.73 ± .01	.69 ± .01	.68 ± .01	.68 ± .01
5	.78 ± .02	.75 ± .02	.76 ± .01	.70 ± .02	.67 ± .01	.68 ± .01
			Backfat, cm			
0	3.18 ± .06	3.49 ± .06	3.34 ± .04	3.12 ± .06	3.55 ± .05	3.33 ± .04
1	3.00 ± .05	3.37 ± .06	3.19 ± .04	3.11 ± .05	3.32 ± .06	3.21 ± .04
2	3.00 ± .06	3.30 ± .05	3.15 ± .04	3.21 ± .08	3.28 ± .08	3.24 ± .06
3	3.04 ± .06	3.20 ± .06	3.12 ± .04	3.11 ± .06	3.38 ± .05	3.24 ± .04
4	2.31 ± .04	2.59 ± .05	2.45 ± .03	2.60 ± .05	2.78 ± .07	2.69 ± .04
5	2.29 ± .05	2.67 ± .05	2.48 ± .04	2.54 ± .04	2.78 ± .04	2.66 ± .03
			Index			
0	162 ± 3.2	145 ± 3.5	154 ± 2.4	164 ± 3.4	140 ± 3.0	152 ± 2.3
1	173 ± 4.2	164 ± 3.6	168 ± 2.8	161 ± 3.6	164 ± 3.8	162 ± 2.6
2	175 ± 3.7	181 ± 4.1	178 ± 2.7	169 ± 4.2	162 ± 3.4	166 ± 2.7
3	175 ± 3.6	160 ± 3.8	168 ± 2.6	157 ± 3.1	144 ± 3.9	150 ± 2.6
4	219 ± 3.7	206 ± 2.8	212 ± 2.3	196 ± 3.3	184 ± 3.9	190 ± 2.5
5	235 ± 5.7	208 ± 4.8	222 ± 3.7	200 ± 4.2	181 ± 3.2	190 ± 2.6

[a]Mean ± standard error.

always possible to adhere to this plan; thus, adjustments in the mating design were required during the breeding season. For example, if three females (designated for the same male) exhibited estrus the same day, an alternate male was utilized for the female not mated to the designated male. This was the primary cause of the variable increase in inbreeding in the lines over generation.

Cumulative inbreeding was less than 5.5% in each of the lines after five generations of selection. Others have reported inbreeding levels of 21.7% (Fredeen et al., 1976) and 17.2% (Leymaster et al., 1979b) after nine and four generations of lean growth selection, respectively. Because inbreeding levels were low and the difference in inbreeding between the S and C lines were small (3.7%), no adjustment for inbreeding level was made in the data.

Line Means. Line means for ADG are presented in table 4. Considerable fluctuation existed between generations in line C, indicating important environmental influences on growth rate. All pigs were in outside dirt lots during the test period of October to February, which undoubtedly explains some of the environmental effects. Fredeen et al. (1976) reported that gilts reared on pasture exhibited greater fluctuations in ADG between generations than did boars reared in confinement.

Fluctuations between generations in ADG also existed in line S, due undoubtedly to environmental influences and to differential selection pressure between generations (table 5). Vangen (1979) also observed fluctuations in ADG between generations in a high index line.

Line means for BF are presented in table 4. A decline in BF thickness in generation 1 occurred in line C suggesting environmental effects on BF. In generation 4, a reduction in

TABLE 5. WEIGHTED SELECTION DIFFERENTIALS BY TRAIT, SEX, LINE AND GENERATION

Generation	Select			Control		
	Sire	Dam	Average	Sire	Dam	Average
			Average daily gain, kg			
1	.09	.04	.06	.03	.002	.02
2	.11	.05	.08	.01	−.02	.003
3	.17	.08	.13	−.02	.01	−.02
4	.08	.07	.07	.02	.01	.02
5	.08	.06	.07	.005	−.001	−.001
Cumulative	.53	.30	.42	.05	.02	.02
Average	.11	.06	.08	.01	−.003	.003
Adjusted			.40			
			Backfat, cm			
1	−.26	−.39	−.32	−.17	−.06	−.11
2	−.06	−.10	−.08	.02	.10	.06
3	.07	−.16	−.04	−.01	−.08	−.04
4	−.29	.03	−.13	.09	−.12	−.01
5	−.36	−.13	−.25	.04	−.07	−.02
Cumulative	−.90	−.75	−.82	−.03	−.22	−.13
Average	−.18	−.15	−.16	−.01	−.04	−.02
Adjusted			−.70			
			Index			
1	35	26	30	15	3	9
2	35	20	27	3	−6	−1.4
3	47	30	38	−5	−1	−3
4	34	19	26	2	8	5
5	38	22	30	.003	.6	.3
Cumulative	188	117	153	16	4	10
Average	38	23	31	3	1	2
Adjusted			143			

TABLE 6. COMPARISON OF WEIGHTED AND UNWEIGHTED SELECTION DIFFERENTIALS FOR THE INDEX IN THE SELECT LINE BY SEX

	Sires			Dams		
Generation	Weighted	Unweighted	Ratio	Weighted	Unweighted	Ratio
1	35	17	2.06	26	25	1.01
2	35	36	.96	20	19	1.05
3	47	44	1.04	30	29	1.03
4	34	31	1.10	19	18	1.03
5	38	38	1.00	22	20	1.11
Average	38	33	1.15	23	22	1.04

BF thickness of approximately .50 cm occurred for both lines. The difference can probably be attributed to a change in the instrument of measurement from a lean-meter to a scanoprobe. Line means for the index reflected changes in ADG and BF.

Selection Differentials. Weighted selection differentials are presented in table 5 by trait-sex-line-generation subclass. Even with random selection, a slight amount of unintentional selection occurred for ADG, BF and I in the C line.

For the S line, the weighted selection differential (averaged across sex) varied from .06 kg in generation 1 to .13 kg in generation 3, for ADG; from −.04 cm in generation 3 to −.32 cm in generation 1, for BF; from 26 I units in generation 4 to 38 in generation 3. The variation in selection differentials is related to the variation in ADG and BF between generations. The I was effective in applying selection pressure to both ADG and BF (.08 kg/generation and −.16 cm/generation for ADG and BF, respectively).

Weighted and unweighted selection differentials for the index are compared in table 6. Except for generation 2, the ratio of weighted to unweighted selection differential was equal to or greater than one for sires. For dams, the ratio was greater than one in every generation. This suggests that natural selection was not working against artificial selection which is in agreement with Leymaster et al. (1979a).

Pooled generation phenotypic standard deviations were .10 kg (ADG), .42 cm (BF) and 31 index units in the S line. The average adjusted selection differential per generation expressed in standard deviation units were .77, −.33 and .92 for ADG, BF and I, respectively. Fredeen et al. (1976) reported average selection differentials per generation (expressed in standard deviation units) of .48 (ADG) and −.52

TABLE 7. LINE DIFFERENCE (S−C) BY TRAIT AND GENERATION

Generation	ADG, kg	BF, cm	Index
0	.006	.005	1.4
1	.015	−.029	5.6
2	.032	−.096	13.1
3	.042	−.121	16.9
4	.045	−.241	22.5
5	.083	−.177	30.8
Total $(S_5-C_5)-(S_0-C_0)$[a]	.077	−.182	29.4
Regression[b]	.014 ± .002	−.045 ± .010	5.76 ± .30

[a]S_5 = select line mean in generation 5; C_5 = control line mean in generation 5; S_0 = select line mean in generation 0; C_0 = control line mean in generation 0.

[b]Regression of line difference on generation number.

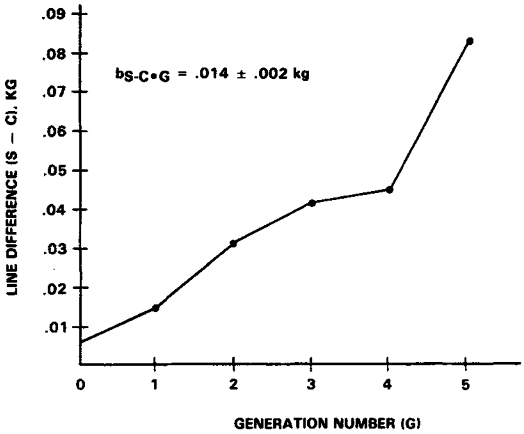

Figure 1. Line difference (S–C) for average daily gain by generation.

(BF) for a lean growth index line. More emphasis was placed on ADG in this experiment than in the experiment of Fredeen et al. (1976). This could be expected since Fredeen and associates used a phenotypic index while the experiment reported herein used an index constructed on economic weights and genetic and phenotypic statistics.

Response. Line differences (S–C) are summarized in table 7. Between generations 3 and 4, the line differences for ADG increased slightly, while the line difference for BF increased sharply. However, between generations 4 and 5 there was a sharp increase in the line difference of ADG and a decrease in the line difference of BF. Line differences in component traits fluctuated (figure 1 and 2) between generations because of fluctuations in selection differentials. Since selection was based on the I, the line difference in I increased at a linear rate, as illustrated by figure 3.

The regression of line difference (S–C) on generation number was .014 ± .002 kg ADG (P<.01), –.045 ± .010 cm BF (P<.01) and 5.76 ± .30 index units (P<.001). In a similar selection experiment (Vangen, 1979) the regression of line difference on generation number was .0067 kg ADG and –.07 cm BF. More emphasis was placed on ADG in this experiment compared to the one conducted by Vangen (1979). This might have been expected since the experiment reported herein used an index constructed on economic weights and genetic and phenotypic statistics as opposed to the phenotypic index used by Vangen (1974).

The total selection response (S_5–C_5 – S_0–C_0) over the five generations was .077 kg ADG, –.182 cm BF and 29.4 index units. Selection based on the I was effective.

Realized Heritability. The realized heritability estimate for the index was .19 ± .029. This trait was fairly responsive to selection pressure. In other experiments realized heritability estimates for phenotypic indexes (involving two traits) varied from .17 for weight of lean cuts at 160 d of age (Leymaster et al., 1979b) to .34 for growth rate and backfat (Vangen, 1977).

Index in Retrospect. In the S line, animals were mass selected on the basis of an I involving ADG and BF: I = 100 + 286.6 (ADG) – 39.4 (BF). Holding the weighting on BF constant (–39.4), the actual weighting applied to

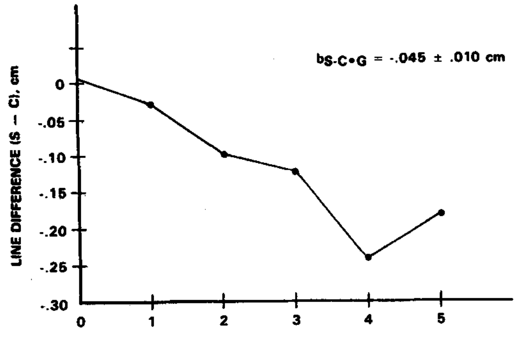

Figure 2. Line difference (S–C) for probe backfat by generation.

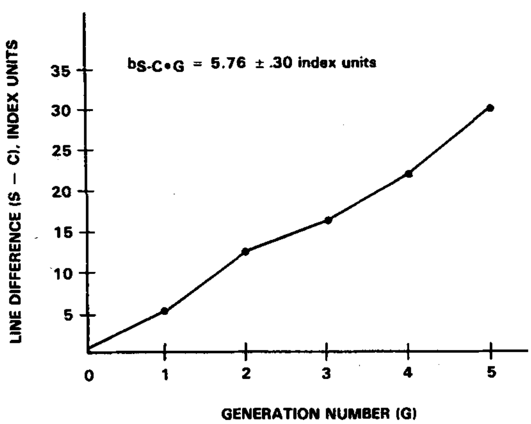

Figure 3. Line difference (S–C) for the index by generation.

ADG in the S line was fairly close (262.8) to the intended weighting. This would suggest that factors such as natural selection or management had little effect on the selection criteria.

Expected Response. The expected response was .034 kg and −.118 cm per generation for ADG and BF, respectively. However, the realized response was .014 kg and −.045 cm for the respective traits. These values are 41 and 38% of the expected response for ADG and BF, respectively.

Possible reasons for the difference between expected and realized response are (1) the genetic statistics utilized in index construction may have been inappropriate for the LG line and (2) the experimental conditions. Hetzer and Miller (1972) reported realized genetic correlations between BF and ADG of −.06 and .23 for Durocs and Yorkshires, respectively. Hutchens and Hintz (1981) indicate that genetic statistics (for ADG and BF) are quite variable among experiments. Pigs were fed in outside dirt lots throughout the study. This probably increased the phenotypic variation as compared to what might have been observed with pigs raised in total confinement. Thus, heritability was decreased.

Discussion

Several studies (Dickerson, 1947; Zoellner et al., 1963; Edwards and Omtvedt, 1971; Robison and Berruecos, 1973; McPhee et al., 1979) have demonstrated that an undesirable genetic relationship exists between ADG and BF. If this is true, single trait selection for ADG or BF should not be used because an undesirable correlated response might occur. Index selection for ADG and BF was effective in increasing ADG and decreasing BF. Theoretical expectations indicate that index selection has a greater relative efficiency than tandem selection and independent culling levels (Hazel and Lush, 1942; Young, 1961). Theoretical expectations are in agreement with experimental evaluations (Sen and Robertson, 1964; Elgin et al., 1970; Doolittle et al., 1972; Eagles and Frey, 1974). Therefore, if simultaneous genetic improvement of two or more traits is desired, index selection should be utilized.

The realized response (in ADG and BF) was less than the expected response. This may be due to inappropriate genetic statistics utilized in index construction and to the experimental conditions. Refinements in calculating genetic statistics, in measurement techniques (for ADG and BF) and in management (confinement feeding and selection within contemporary groups) should result in a greater rate of genetic improvement when index selection is utilized compared to what is being achieved by the industry at present.

These data also suggest that natural selection was not working against index selection.

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