October 1988

CORRELATED RESPONSES OF CARCASS AND REPRODUCTIVE TRAITS TO SELECTION FOR RATE OF LEAN GROWTH IN SWINE

E. R. Cleveland
University of Nebraska-Lincoln

R. K. Johnson
University of Nebraska-Lincoln, rjohnson5@unl.edu

P. J. Cunningham
University of Nebraska-Lincoln

CORRELATED RESPONSES OF CARCASS AND REPRODUCTIVE TRAITS TO SELECTION FOR RATE OF LEAN GROWTH IN SWINE[1]

E. R. Cleveland[2], R. K. Johnson[3] and P. J. Cunningham[4]

University of Nebraska, Lincoln 68583–0908

ABSTRACT

Mass selection for an index of increased postweaning average daily gain and decreased backfat thickness was practiced for five generations. Litter size and weight for 221 gilt litters, birth weight and nipple number for 2,242 piglets and weaning weight at 42 d of age for 2,111 pigs were recorded. Carcass measurements were taken on 331 pigs. Differences between means of the lines (select control) were regressed on cumulative selection differential of the index. These regression coefficients were negative ($P > .10$) for total number born, number born alive, number weaned per litter, nipple number and carcass backfat thickness. Coefficients were positive ($P > .10$) for individual pig and litter weights at birth and weaning and for the carcass traits of length, longissimus muscle area and percentage of ham and loin. Absolute values of realized genetic correlations of index with traits evaluated were all .35 or less except the correlation with carcass backfat, which was −.84. None of these was significant; therefore, index selection for lean growth should have little effect on litter size and weight but may have a beneficial effect on carcass backfat.

(Key Words; Pigs, Selection Index, Growth, Correlated Responses, Carcass Composition, Reproduction.)

Introduction

Index selection for increased postweaning average daily gain (ADG) and decreased backfat thickness (BF) has resulted in faster gaining, leaner swine (Ollivier, 1977; Sather and Fredeen, 1978; Vangen, 1979; Cleveland et al., 1982). Correlated responses to selection for lean growth need to be evaluated to design optimum selection programs (Tess et al., 1983). Hetzer and Miller (1970, 1972, 1973) and Berruecos et al. (1970) have reported correlated responses to selection for low BF in swine, and correlated responses to selection for growth rate have been evaluated by Rahnefeld (1973), Garnett and Rahnefeld (1976) and Rahnefeld et al. (1983). Correlated responses to index selection for rate of lean growth have been reported also (Vangen, 1974, 1980a,b; Fredeen and Mikami, 1986a,b,c), but precision of these estimates is generally low.

The objective of this study was to estimate correlated responses in carcass and reproductive traits to five generations of index selection for increased postweaning ADG and decreased BF.

Materials and Methods

The University of Nebraska Gene Pool population of swine was established by the introduction of 13 breeds of sire into a Hampshire female population (Zimmerman and Cunningham, 1975). After introduction of the last breed in 1965, the 14-breed composite population was closed to outside introductions and maintained by random mating until 1967. Then two lines were formed; one was mass-selected for increased ovulation rate, and the other was selected randomly (Zimmerman and Cunningham, 1975).

Third-generation select and control line pigs from the ovulation rate experiment were reciprocally crossed, and 64 litters were produced. At weaning pigs were assigned randomly within litter to either line LG or C. Line LG was mass-selected for an index of postweaning ADG and probed BF, and line C was selected randomly. Selection for the index ($I = 100 + 286.6\ [\text{ADG, kg}] - 39.4\ [\text{BF, cm}]$) was conducted over five generations (Cleveland et al., 1982).

[1]Published as Paper No. 6990 Journal Series., Nebraska Agric. Exp. Sta.

[2]Present address: Univ. Hawaii, Hilo 96720.

[3]Dept. of Anim. Sci.

[4]Present address: Booneville, IA 50038.

Received June 15, 1987.

Accepted January 29, 1988.

Numbers of litters, sires and pigs on which data were recorded each generation are shown in Table 1. Generation interval was 1 yr. Total number born (all fully formed piglets), number born alive, number weaned at 42 d, individual birth weight of live pigs, litter birth weight of live pigs, individual weaning weight, litter weaning weight and number of nipples on each pig were recorded. Information concerning birth weight, weaning weight and number of nipples was available for the base generation and for the subsequent five generations. Litter size and weight were considered traits of the dam and were measured on gilts selected from generations 0 through 4.

Before assignment to lines, a random sample of 20 males and 20 females from the base generation were slaughtered for carcass evaluation. In each of the following generations, one or two pigs were selected randomly from each litter for carcass evaluation. Pigs were slaughtered at a commercial abattoir at an average live weight of 101.6 kg (SD = 8.6 kg). Carcass backfat was the mean of measurements on the midline at the first rib, last rib and last lumbar vertebra, and carcass length was measured from the anterior edge of the first rib to the anterior edge of the aitch bone. Both traits were measured on hot carcasses. Trimmed hams and loins were weighed after a 24-h chill. Percentage of ham and loin was the total weight of trimmed ham and loin expressed as a percentage of cold carcass weight. Longissimus muscle area was measured between the 10th and 11th ribs of the chilled loin.

Weaning weights were fitted to a model that included the effects of line, generation, line × generation interaction and weaning age as a covariate. The regression coefficient of weaning weight on age was used to adjust weaning weights to an age of 42 d; adjusted weights of siblings were summed to obtain adjusted litter weaning weights. Adjusted means of carcass traits were obtained within sex from a model that included the effect of line, year, line × year interaction and carcass weight as a covariate. Adjusted means for each sex were averaged to obtain the line means used in the calculation of correlated responses.

Correlated responses were evaluated from regressions of differences between lines each generation (LG − C) on weighted cumulative selection differential of the index. The selection differential of each parent was weighted by the number of offspring on which the index was

TABLE 1. NUMBER OF LITTERS PRODUCED, NUMBER OF SIRES AND NUMBER OF PIGS EVALUATED PER LINE-GENERATION SUBCLASS[a]

Generation	Litters farrowed		Sires		Pigs weaned		Nipple number		Carcass barrows		Carcass gilts	
	LG	C	LG	C	LG	C	LG	C	LG	C	LG	C
0						517	139	143		20		20
1	21	21	12	12	153	147	182	167	16	13	15	13
2	23	21	10	12	170	148	197	168	16	15	15	16
3	20	24	10	12	150	158	190	214	14	13	13	15
4	23	18	10	14	172	129	213	163	17	13	15	7
5	23	27	11	13	171	196	222	244	18	22	9	16
Avg	22.0	22.2	10.6	12.6	163.2	215.8	190.5	183.2	16.2	16.0	13.4	14.5

[a]LG = select line, C = control line.

recorded (Cleveland et al., 1982). The variance of the regression coefficient was adjusted for variance due to genetic drift as described by Hill (1972) and Notter et al. (1976).

Heritabilities were calculated for each trait except index from a model that included line-generation, sire within line-generation, dam and sex, where appropriate. Realized heritability for the index (Cleveland et al., 1982) was used. Average inbreeding coefficients for the fifth generation were 5.15 and 1.49% for litters and 5.31 and .89% for dams for lines LG and C, respectively. These were used to calculate rates of inbreeding and effective population sizes (Cleveland et al., 1982).

Realized genetic correlations were estimated from regressions of differences between lines for the correlated traits on weighted cumulative selection differential of the index (Rutledge et al., 1973). Significance levels for genetic correlations were assumed to be the same as those for the regressions of responses in correlated traits on cumulative selection differential of the index.

Results and Discussion

Total cumulative selection differential for the index was 143 points (Cleveland et al., 1982). The realized heritability was .19 ± .03, and the total genetic change was estimated to be 28.8 ± 1.5 points.

Standard errors of regression coefficients of differences between lines on cumulative selection differential of the index calculated both before and after adjustment for genetic drift are presented in tables of results. Inbreeding coefficients were relatively low, yet adjusting standard errors for variance due to genetic drift increased standard errors of regression coefficients by as much as 325%. The magnitude of the adjustment depended on the estimated heritability of the correlated trait and its genetic correlation with the index. Standard errors could not be adjusted for genetic drift when the estimated heritability of the trait was negative. Significance levels of regression coefficients were determined with the adjusted standard errors.

Means and regression coefficients are presented in Table 2 for litter traits. For total number born, number born alive and number weaned/litter, the estimated response was negative but not significant. Vangen (1980b) reported that index selection for lean growth in a Norwegian Landrace line resulted in a positive correlated response for total number born and number born alive/litter, but in a negative correlated response for number/litter at 42 d. However, none of the correlated responses in their study was significant. Fredeen and Mikami (1986a) reported that in the last generation of selection a Lacombe line selected for rate of lean growth was equivalent in total number born/litter, but superior in number weaned/litter, to a control line. Selection for weight of lean cuts at a constant age in a Yorkshire line (DeNise et al., 1983) resulted in a negative ($P > .05$) correlated response for litter sizes at 1 and 7 d in first-parity gilts. Correlated responses were negative ($P < .05$) in second-parity sows for litter sizes at 1, 7 and 21 d.

Correlated responses in litter size to selection for rate of lean growth were variable among experiments. However, our results suggest that index selection for rate of lean growth will not have a large effect on litter size.

Line LG had consistently heavier litters at birth and weaning than line C (Table 2). However, the regressions on cumulative selection differential for the index were not significant. Vangen (1974) reported correlated responses ($P > .05$) that were positive for litter weight at birth but negative for litter weight at 42 d to index selection for rate of lean growth. DeNise et al. (1983) found that selection for weight of lean cuts resulted in negative correlated responses for litter weights at birth and 21 d at first and second parity. However, the correlated responses were significant only for litter weights at second parity. Our results, and those of similar experiments reported in the literature, suggest that index selection for rate of lean growth will have very little effect on litter weights.

Means and regression coefficients for pig weights and number of nipples are presented in Table 3. Regressions on cumulative selection differential of the index were positive ($P > .10$) but small for both birth and weaning weights. Vangen (1980b) reported positive correlated responses for birth weight ($P < .05$) and 42-d weight ($P > .05$) to index selection for rate of lean growth, which is consistent with our results. Index selection for rate of lean growth may have a small positive effect on pig weights at birth and 42 d of age.

The regression coefficient of differences between the lines on cumulative selection differential of the index was negative but was

TABLE 2. MEANS AND REGRESSION COEFFICIENTS OF LINE DIFFERENCES ON CUMULATIVE SELECTION DIFFERENTIAL OF THE INDEX FOR LITTER TRAITS

	LG[a]		C[a]		Regression coefficient		
Trait and generation	$\bar{x}$	SE	$\bar{x}$	SE	b	SE[b]	SE[c]
No. born							
0	9.8	.7	8.9	.4			
1	9.6	.5	8.8	.7			
2	9.6	.7	9.0	.7	−.0033	.0008	.0026
3	9.4	.4	8.7	.8			
4	9.6	.5	9.1	.4			
No. born alive							
0	9.0	.6	8.3	.4			
1	9.4	.5	8.8	.7			
2	9.4	.7	9.0	.7	−.0005	.0020	.0020
3	8.9	.5	8.5	.7			
4	9.4	.5	8.7	.4			
No. weaned							
0	7.3	.6	7.0	.5			
1	7.4	.6	7.0	.6			
2	7.5	.6	6.6	.6	−.0003	.0035	.0036
3	7.5	.4	7.2	.6			
4	7.4	.5	7.2	.4			
Litter birth weight, kg							
0	11.7	.8	11.6	.7			
1	12.0	.6	11.5	.8			
2	11.4	1.0	10.9	.8	.0027	.0040	.0040
3	10.7	.7	9.7	.8			
4	10.7	.6	10.5	.5			
Litter weaning weight, kg							
0	82.4	6.9	79.9	6.4			
1	89.3	7.6	84.3	7.4			
2	74.3	6.9	64.0	6.0	.0345	.0434	.0557
3	81.7	4.7	70.2	6.3			
4	74.5	4.9	70.6	3.8			

[a]LG = lean growth and C = control line.

[b]SE = standard error of regression coefficient, not adjusted for genetic drift variance.

[c]SE = standard error of regression coefficient, adjusted for genetic drift variance.

not significant for nipple number (Table 3). Even though the trend over generations was negative for nipple number, the trend was positive for weights of pigs and litter at weaning. Thus, selection was not detrimental to sow productivity.

Means and responses per unit of selection differential of the index are presented in Table 4 for carcass traits. Differences between lines (LG − C) for carcass length and percentage ham and loin were variable over generations, but LG-line pigs had consistently larger longissimus muscle area than C-line pigs. Regression coefficients were positive ($P > .10$) for carcass length, longissimus muscle area and percentage ham and loin.

Fredeen and Mikami (1986c) reported correlated responses in carcass traits to index selection for rate of lean growth similar to our findings. Vangen (1980a) found a significant positive correlated response for carcass length and percentage ham and loin, and a nonsignificant positive correlated response for longissimus muscle area to index selection for rate of lean growth. DeNise et al. (1983) reported a nonsignificant negative correlated response in longissimus muscle are, but a significant positive correlated response for carcass length, to selection for weight of lean cuts and a nonsignificant positive correlated response for percentage lean in the carcass.

Line LG pigs had less carcass backfat than line C pigs (Table 4). The average response per unit of selection differential of the index was

TABLE 3. MEANS AND REGRESSION COEFFICIENTS OF LINE DIFFERENCES ON CUMULATIVE SELECTION DIFFERENTIAL OF THE INDEX FOR BIRTH WEIGHT, WEANING WEIGHT AND NIPPLE NUMBER

	LG[a]		C[a]		Regression coefficient		
Trait and generation	$\bar{x}$	SE	$\bar{x}$	SE	b	SE[b]	SE[c]
Birth weight, kg							
0			1.55	.01			
1	1.31	.02	1.41	.02			
2	1.28	.02	1.31	.03			
3	1.21	.02	1.20	.02	.0002	.0005	.0005
4	1.20	.02	1.14	.02			
5	1.13	.02	1.20	.02			
Weaning weight, kg							
0			12.64	.14			
1	11.30	.22	11.41	.22			
2	12.08	.22	11.96	.23			
3	9.91	.19	9.62	.18	.0051	.0031	.0031
4	10.92	.18	9.79	.20			
5	10.02	.22	9.72	.16			
Nipple no.							
0	13.12	.10	13.30	.09			
1	12.49	.10	12.79	.10			
2	12.91	.08	12.92	.10	−.0053	.0017	.0029
3	13.01	.12	13.56	.12			
4	12.95	.13	13.83	.15			
5	12.80	.07	13.59	.08			

[a]LG = lean growth and C = control line.

[b]SE = standard error of regression coefficient, not adjusted for genetic drift variance.

[c]SE = standard error of regression coefficient, adjusted for genetic drift variance.

negative ($P < .15$). In an evaluation of sixth-generation barrows, Cleveland et al. (1983) found that line LH had 14% less probe BF and 11% less body fat than line C. Total estimated correlated response in carcass backfat in this study was calculated to be −3.9 mm (−.0276 × 143). This estimate of correlated response in carcass backfat of 10% is similar to that found in sixth-generation barrows and is higher than the estimated total response in probed BF of −2.25 mm (Cleveland et al., 1982). Similar changes in carcass backfat from selection for weight of lean cuts (DeNise et al., 1983) and index selection for rate of lean growth (Fredeen and Mikami, 1986c) have been reported. Thus, index selection for rate of lean growth may have a desirable effect of several carcass traits, particularly BF.

Estimates of genetic correlations and heritabilities are presented in Table 5. None of the realized genetic correlations was significant. Neither heritabilities nor genetic correlations with index are estimated very precisely, but these, and the phenotypic standard deviation of each trait, are included for completeness. Realized heritability of index, used to calculate realized genetic correlations, was .19 (Cleveland et al., 1982). The sire component of variance in the hierarchal analysis of variance was negative for number born alive/litter, litter birth weight and pig weights at birth and 42 d of age, and for these traits, realized genetic correlations with index could not be estimated.

Genetic correlations of the index with litter size, litter weight and most carcass traits were small (absolute values of $r_g \leqslant .35$). The realized genetic correlation of the index with carcass backfat was high (−.84). In conclusion, index selection for rate of lean growth in swine should have little effect on litter sizes and weights at birth or 42 d of age, but may have beneficial effects of some carcass traits, particularly carcass BF and percentage lean in the carcass.

TABLE 4. MEANS AND REGRESSION COEFFICIENTS OF LINE DIFFERENCES ON CUMULATIVE SELECTION DIFFERENTIAL OF THE INDEX FOR CARCASS TRAITS

Trait and generation	LG[a]		C[a]		Regression coefficient		
	$\bar{x}$	SE	$\bar{x}$	SE	b	SE[b]	SE[c]
Longissimus muscle area, cm^2							
0			27.7				
1	29.3	.7	28.4	.8			
2	30.7	.7	29.3	.7			
3	30.8	.7	28.4	.7	.0103	.0051	.0098
4	29.4	.7	27.9	.9			
5	29.3	.8	27.9	.6			
Ham and loin, %							
0			41.9				
1	42.3	.3	42.4	.4			
2	41.1	.3	41.2	.3			
3	40.4	.4	39.7	.4	.0038	.0024	.0037
4	39.5	.3	39.0	.4			
5	39.2	.4	39.0	.3			
Length, cm							
0			77.0				
1	77.4	.4	77.3	.4			
2	78.7	.4	79.1	.4			
3	78.1	.4	77.5	.4	.0017	.0026	.0034
4	78.8	.3	78.8	.5			
5	77.0	.3	76.8	.3			
Backfat, mm							
0			38.9				
1	39.4	.9	40.2	1.0			
2	39.4	.9	39.9	.9			
3	38.6	1.0	38.9	1.05	−.0276	.0123	.0133
4	37.6	.9	39.1	1.2			
5	37.6	1.0	43.1	.8			

[a]LG = lean growth and C = control line.

[b]SE = standard error of regression coefficient, not adjusted for genetic drift variance.

[c]SE = standard error of regression coefficient, adjusted for genetic drift variance.

TABLE 5. HERITABILITIES, STANDARD DEVIATIONS AND REALIZED GENETIC CORRELATIONS OF LITTER SIZE AND WEIGHT, PIG WEIGHTS AND CARCASS TRAITS WITH INDEX

Trait	Heritability[a]	SD	Genetic correlation
No. born/litter	.11	2.80	−.24
No. born alive/litter	−.07	2.73	UE[c]
No. weaned/litter	.03	2.63	−.05
Litter birth wt, kg	−.07	3.30	UE
Litter weaning wt, kg	.22	28.77	.17
Birth wt, kg	−.36	.30	UE
Weaning wt, kg	−.46	2.57	UE
Nipple number	.45	1.49	−.35
Longissimus muscle area, cm^2	.80	3.86	.20
Ham and loin, %	.37	1.89	.22
Carcass length, cm	.25	1.91	.12
Carcass backfat, mm	.20	5.00	−.84
Index[b]	.19	29.4	

[a]Estimated from correlation among paternal half-sibs.

[b]Realized heritability of index. (Cleveland et al., 1982).

[c]UE = unestimated.

Literature Cited

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

Cleveland, E. R., P. J. Cunningham and E. R. Peo, Jr. 1982. Selection for lean growth in swine. J. Anim. Sci. 54:719.

Cleveland, E. R., R. K. Johnson and R. W. Mandigo. 1983. Index selection and feed intake restriction in swine. I. Effect on rate and composition of growth. J. Anim. Sci. 56:560.

DeNise, R.S.K., K. M. Irvin, L. A. Swiger and R. F. Plimpton. 1983. Selection for increased leanness of Yorkshire swine. IV. Indirect responses of the carcass, breeding efficiency and preweaning litter traits. J. Anim. Sci. 56:551.

Fredeen, H. T. and H. Mikami. 1986a. Mass selection in a pig population: Correlated responses in reproductive performance. J. Anim. Sci. 62: 1523.

Fredeen, H. T. and H. Mikami. 1986b. Mass selection in a pig population: correlated responses in preweaning growth. J. Anim. Sci. 62:1533.

Fredeen, H. T. and H. Mikami. 1986c. Mass selection in a pig population: correlated changes in carcass merit. J. Anim. Sci. 62:1546.

Garnett, I. and G. W. Rahnefeld. 1976. Mass selection for post-weaning growth in swine. V. Correlated response of reproductive traits and pre-weaning growth. Can. J. Anim. Sci. 56:791.

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.

Hetzer, H. O. and L. R. Miller. 1973. Selection for high and low fatness in swine: Correlated responses of various carcass traits. J. Anim. Sci. 37:1289.

Hill, W. G. 1972. Estimation of realized heritabilities from selection experiments. II. Selection in one direction. Biometrics 28:767.

Notter, D. R., G. E. Dickerson and J. A. DeShazer. 1976. Selection for rate and efficiency of lean gain in the rat. Genetics 84:125.

Ollivier, L. 1977. Dix ans d'une experience de selection individuelle sur des verrats utilisés en insemination artificielle. I. Responses observées sur des caracteres de croissance de carcasse et de qualité de viande. Ann. Genet. Sel. Anim. 9:353.

Rahnefeld, G. W. 1973. Mass selection for postweaning growth in swine. III. Correlated response in weaning weight and feed efficiency to recurrent selection for postweaning average daily gain in swine. Can. J. Anim. Sci. 53:173.

Rahnfeld, G. W., R. L. Cliplef, I. Garnett and R. M. McKay. 1983. Mass selection for postweaning growth in swine. VI. Means, heritabilities, genetic and phenotypic correlations, and correlated response of carcass traits. Can. J. Anim. Sci. 63:49.

Rutledge, J J., E. J. Eisen and J. E. Legates. 1973. An experimental evaluation of genetic correlation. Genetics 75:709.

Sather, A. P. and H. T. Fredeen. 1978. Effect of selection for lean growth rate upon feed utilization by the market hog. Can. J. Anim. Sci. 58:285.

Tess, M. W., G. L. Bennett and G. E. Dickerson. 1983. Simulation of genetic changes in life cycle efficiency of pork production. II. Effect of components on efficiency. J. Anim. Sci. 56:354.

Vangen, O. 1974. Preweaning weights in lines of pigs selected for rate of gain and thickness of backfat. Acta Agric. Scand. 24:195.

Vangen, O. 1979. Studies on a two trait selection experiment in pigs. II. Genetic changes and realized genetic parameters in the traits under selection. Acta Agric. Scand. 29:305.

Vangen, O. 1980a. Studies of a two trait selection experiment in pigs. III. Correlated responses in daily feed intake, feed conversion and carcass traits. Acta Agric. Scand. 30:125.

Vangen, O. 1980b. Studies on a two trait selection experiment in pigs. V. Correlated responses in reproductive performance. Acta Agric. Scand. 30:309.

Zimmerman, D. R. and P. J. Cunningham. 1975. Selection for ovulation rate in swine: population, procedures and ovulation response. J. Anim. Sci. 40:61.