March 1983

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INDEX SELECTION AND FEED INTAKE RESTRICTION IN SWINE. I. EFFECT ON RATE AND COMPOSITION OF GROWTH[1]

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Summary

The objectives of this experiment were to determine the effects of index selection for increased average daily gain and decreased backfat, and the effects of restriction of daily feed intake, on rate and composition of growth in swine. A total of 53 barrows from select and control lines were randomly assigned to three feeding levels at 83 d of age, and 33 littermate barrows were slaughtered to establish initial body composition. The trial was approximately 105 d and the feeding levels were twice daily to appetite (AP), once daily feeding of 91% of appetite (AP91) and once daily feeding of 82% of appetite (AP82). At slaughter, all pigs were dissected and analyzed for chemical composition. Average daily gain was higher (P<.01) while backfat was lower (P<.001) for select than for control pigs. Restriction of feed intake reduced (P<.01) growth rate. Even at heavier final weights, select pigs had a greater (P<.001) proportion of lean than control pigs. Pigs fed the AP91 and AP82 levels of intake had a greater (P<.01) proportion of lean than pigs fed the AP level. Daily gains of protein, water and lean were higher (P<.01) for select than for control pigs. However, daily fat gain was lower (P<.05) for select pigs. Restricting feed intake reduced (P<.05) daily fat gain, but daily gains of protein, water and lean were similar for pigs on the AP and AP91 levels. However, daily gains of protein, water and lean were lower for pigs on the AP82 level than for those on the other regimens. (Key Words: Swine, Selection, Intake, Growth, Composition.)

Introduction

Improved conversion of dietary energy into carcass lean should be a major objective of long term swine improvement programs. Unfortunately, the results of experiments in which there was direct selection for food conversion ratio are disappointing in that little change occurred (Dickerson and Grimes, 1947; Jungst et al., 1981). However, index selection for increased growth rate and decreased backfat thickness has been effective (Ollivier, 1977, Sather and Fredeen, 1978; Vangen, 1979, 1980).

Moderate restriction of daily feed intake reduces rate of fat growth more than the rate of lean growth of market pigs (Cöp, 1974). It is a common practice in many countries, but is not widespread in the United States. However, restricting the intake of growing pigs may become a useful management practice, particularly if feed costs rise more rapidly than other production costs. Optimum feed restrictions may depend on the rate and composition of growth and may differ for different genetic stocks.

Cleveland et al. (1982) reported the results of five generations of index selection for increased postweaning average daily gain and decreased backfat. Average daily gain increased by 12.5% and backfat decreased by 5.4%. The objectives of the present experiment were to evaluate the effects of index selection for increased growth rate and decreased backfat and the effects of restriction of daily feed intake on the rate, efficiency and composition of growth.

Materials and Methods

Populations. From 1958 to 1965, the University of Nebraska Gene Pool population was established by the introduction of 13 breeds of swine into a Hampshire female

[1] Published as Paper No. 6867, Journal Ser., Nebraska Agr. Exp. Sta.

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population (Zimmerman and Cunningham, 1975). The 14 breed synthetic population was closed in 1965 and maintained by random mating until the initiation of an ovulation rate selection experiment in 1967. Third generation ovulation rate select and control line boars and sows were reciprocally crossed and the litters, born during 1971, formed generation 0 select and control lines to evaluate index selection for increased postweaning average daily gain (ADG) and decreased backfat (BF).

Cleveland et al. (1982) reported the results of five generations of index selection for ADG and BF. Ad libitum feeding over the interval of 56 d to 79 kg was used and the index was: I = 100 + 286.6 (ADG) − 39.4 (BF). The highest indexing generation 5 progeny from the select line were mated and Caesarian section-derived litters (by 10 different sires) were used to repopulate the line in new swine facilities. At the same time, the ovulation rate control line was repopulated with Caesarian section-derived litters produced by mating randomly selected generation 8 boars and sows. Following repopulation, the lines were maintained by random selection and random mating. The index control line was not repopulated. Differences between the ovulation rate select and control lines have been small for daily gain, probe backfat (Newton et al., 1977) and carcass traits (England et al., 1977). Therefore, the ovulation control line was deemed to be an acceptable control for the index line. The present experiment compares a random sample of index select barrows with ovulation rate control line barrows. Litters were born during 1979 and represent six generations of index selection followed by one generation of relaxed selection.

Experimental Procedure. After weaning at 28 d of age, 86 barrows were maintained in nursery facilities until they were about 75 d of age. They were moved to an environmentally controlled individual feeding unit and, at a mean age of 83 d (SD = 4.5), they were weighed and ultrasonically probed for backfat thickness. The mean starting weight was 25.3 kg (SD = 6.6). Fifty-three barrows (23 index select and 30 control line) were randomly allotted within line and fed twice daily to appetite (AP), 91% of appetite intake (AP91) or 82% of appetite intake (AP82). Once daily feeding was used for AP91 and AP82 treatments. The other 33 barrows were slaughtered to establish the initial body composition of the lines. The initial slaughter sample (9 index and 24 control line) included at least one barrow from each litter represented by the test group. The litters were produced by eight index and 15 control line sires.

Pigs on the AP regimen were given access to the feeder for two 1-h periods/day. Body weight and feed intake were measured weekly, and average daily feed intake for the week was regressed on midweek weight. Pigs on the AP91 and AP82 regimens also were weighed weekly and, based on the AP regression equations, their average daily feed intake was calculated for the next week.

During the next week, pigs on the AP91 and AP82 regimens were given one feeding/day of 91 or 82%, respectively, of the calculated AP intake. The diet was 16% protein corn-soybean meal (table 1); and pigs were fed for approximately 105 d (SD = 3.3), after which they were weighed, ultrasonically probed for backfat and slaughtered. Two feedings/day (AP) vs one feeding/day (AP91 and AP82) was confounded with feeding regimen. Possibly, this could affect results. However, Friend and Cunningham (1964) fed pigs the same quantity of food in one meal or five meals/day and found little effect of frequency of eating on efficiency of calorie conversion to fat and protein gain or on

TABLE 1. COMPOSITION OF DIET

Component	Percentage
Corn (IFN 4-02-992)	75.46
Soybean meal, 44% crude protein (IFN 5-04-604)	20.93
Dicalcium phosphate (IFN 6-01-080)	1.42
Limestone (IFN 6-02-632)	.64
Iodized salt (IFN 6-04-151)	.50
Trace mineral mix[a]	.05
Vitamin premix[b]	1.00
Total	100.00

[a]Contributed the following in mg/kg of diet: Zn, 100; Fe, 50; Mn, 27.5; Cu, 5.0; Co, .5; I, .75.

[b]Contributed the following per kg of diet: vitamin A, 3,300 units; vitamin B_{12}, 22.05 μg; vitamin D_3, 440 ICU; vitamin E, 22.05 IU; riboflavin, 2.2 mg; D-pantothenic, 13.23 mg; niacin, 17.64 mg; choline chloride, 110.23 μg; ethoxquin, 4.41 mg; menadione sodium bisulfate, 2.2 mg.

the digestibility of the diet. The group fed once daily had a higher rate of live weight gain, which was attributed to the effect of fill, because carcass weight gains were similar for the two groups. Very small differences were found for carcass measurements.

Before slaughter, all pigs were held off feed for 36 h. They were electrically stunned, the jugular vein was severed and all blood was collected. The head and hooves were removed and the carcass was skinned. Each pig was divided into four fractions. Fraction A included the blood, head, hooves, hair, skin and minimal fat removed while skinning. All viscera were included in fraction B. Hot carcasses were dissected into fraction C, the edible lean and fat, and fraction D, the bone, cartilage and minimal fat and lean that could not be removed from the bones.

Each fraction was thoroughly ground and blended and analyzed for fat, protein, ash and water (AOAC, 1975). The total weight of water, fat, protein and ash was calculated for each fraction of each animal, and the weight of each component in each fraction was summed to get the estimated weight of water, fat, protein and ash in the animal at the time of slaughter.

Data Analyses. For each pig in the initial slaughter group, fat, protein, water, ash and lean (protein + water + ash) for total carcass and for fraction C were expressed as a percentage of 83-d weight. The percentages of each component were fitted to a model with the effects of initial weight and probe backfat. If an independent variable was not significant, it was deleted from the model and the data were reanalyzed. Preliminary analyses resulted in no significant line by regression coefficient interactions; thus, the regression coefficients were pooled within line. The regression coefficients (table 2) obtained from these analyses were used to estimate the 83-d composition of the littermate test pigs. The percentage of each component was estimated by:

$$\text{Component percentage in test pig} = \text{Component percentage in littermate} + b_{C\%\cdot BF}\,(BF_{TP} - BF_{LM}) + b_{C\%\cdot WT}\,(WT_{TP} - WT_{LM}),$$

where,

$b_{C\%\cdot BF}$ and $b_{C\%\cdot WT}$ = regression coefficient of the component percentage on backfat (BF) or weight (WT), respectively, in the initial slaughter group and TP and LM designate the test pig and littermate, respectively.

TABLE 2. SIGNIFICANT REGRESSION COEFFICIENTS OF COMPOSITION PERCENTAGE ON BACKFAT AND WEIGHT FOR THE INITIAL SLAUGHTER GROUP

Trait[a]	b_{BF}[b], cm	b_{WT}[c], kg
Percentage		
Fat	11.00	
Protein		
Water		−.257
Ash		
Lean		−.267
Fat in C	6.14	.093
Protein in C		.071
Water in C		.205
Ash in C		.002
Lean in C		.278

[a] C is fraction consisting of edible lean and fat.

[b] b_{BF} = regression of percentage of each component on backfat.

[c] b_{WT} = regression of percentage of each component on weight.

The estimated percentage of each component and the initial weight of each test pig were used to estimate the total initial weight of each component in each test pig. The weight gain for each component was measured as the difference between the weight of the component in the test pig at slaughter and the estimated initial component weight.

All variables were analyzed with a model that included the effects of line, feeding level, line × feeding level and initial test weight. The mean difference between the index and control lines, averaged over feeding levels, and the orthogonal contrasts among feeding levels of ½(AP + AP91) vs AP82 and AP vs AP91 were calculated. The interaction of these contrasts with line were calculated, but were not significant for any trait. When not significant, initial weight was deleted from the model and the data were reanalyzed.

Results

Composition of Initial Slaughter Group. Line means for weight and composition of the body fractions in the initial slaughter group are presented in table 3. The initial slaughter

sample of control barrows was 2.8 d older, and consequently, about 3 kg heavier than the sample of index barrows. Thus, the weight of each fraction was also heavier; however, the line difference was significant only for viscera weight (fraction B).

In general, the compositional differences between the lines were small. But protein percentage in control barrows was significantly higher in fractions A, C and D. As a result, the percentage of protein in the total body was also significantly higher (.7%) for control barrows. Index barrows had 2.3% less fat and 2.3% more water in the viscera than did control barrows.

Performance Traits. Initial weights, final weights and feed intakes are presented in table 4. Achieved levels of intake restriction were calculated within line by expressing intake$\cdot$d$^{-1}\cdot$ midweight^{-1} for pigs receiving the AP91 and AP82 feeding regimens as a percentage of the value for pigs on the AP level of feeding. Achieved restrictions for index and control barrows were 91.9 and 92.3%, respectively, for the AP91 regimen and 86.5 and 84.6% for the AP82 regimen. The achieved restrictions were higher than target values for the AP82 regimen. However, intake per unit of midweight was very similar for index and control barrows on each

TABLE 3. LINE MEANS AND STANDARD ERRORS FOR WEIGHT AND COMPOSITION OF BODY FRACTIONS IN THE INITIAL SLAUGHTER GROUP

Item[a]	Index select line Mean ± SE	Control line Mean ± SE
Number	9	24
Fraction A		
Weight, kg	6.39 ± .63	6.82 ± .39
Fat, %	27.2 ± 1.5	26.6 ± .9
Protein, %[b]	14.4 ± .4	15.3 ± .2
Water, %	55.2 ± 1.3	54.3 ± .8
Ash, %[b]	2.5 ± .2	2.9 ± .1
Fraction B		
Weight, kg[b]	4.07 ± .40	4.76 ± .25
Fat, %[b]	6.6 ± .9	8.9 ± .5
Protein, %	12.5 ± .2	12.2 ± .1
Water, %[b]	75.9 ± .7	73.6 ± .5
Ash, %	1.7 ± .4	2.0 ± .3
Fraction C		
Weight, kg	8.13 ± 1.40	9.84 ± .86
Fat, %[c]	17.4 ± 1.3	17.2 ± .8
Protein, %[bc]	15.1 ± .3	16.1 ± .2
Water, %[c]	66.2 ± 1.1	65.0 ± .6
Ash, %[c]	.8 ± .03	.8 ± .02
Lean, %[c]	82.1 ± 1.3	81.9 ± .8
Fraction D		
Weight, kg	3.14 ± .29	3.31 ± .18
Fat, %	13.8 ± .7	13.9 ± .4
Protein, %[b]	16.8 ± .3	17.8 ± .2
Water, %[b]	57.6 ± .8	55.4 ± .5
Ash, %[b]	10.5 ± .5	11.7 ± .3
Body fat, %[c]	18.0 ± .9	17.8 ± .5
Body protein, %[b]	14.6 ± .2	15.3 ± .1
Body water, %[c]	63.2 ± .7	62.4 ± .4
Body ash, %[c]	2.9 ± .1	3.1 ± .1
Body lean, %[c]	80.7 ± .8	80.8 ± .5

[a]Fraction A = blood, head, skin, hair and hooves; fraction B = viscera; fraction C = edible lean and fat and fraction D = bone, cartilage and unseparable fat and lean.

[b]Line difference (P<.05).

[c]Body weight included in model as a covariate.

TABLE 4. MEAN PERFORMANCE, STANDARD DEVIATIONS (IN PARENTHESES) AND ACHIEVED RESTRICTION FOR EACH LINE ANE FEEDING LEVEL

Trait	Index select line			Control line		
	AP	AP91	AP82	AP	AP91	AP82
No.	8	8	7	10	10	10
Starting weight, kg	23.7 (4.8)	27.0 (6.2)	24.6 (5.6)	25.9 (7.3)	23.6 (6.0)	26.7 (8.9)
Final weight, kg	106.1 (13.9)	104.0 (11.0)	89.0 (6.6)	99.8 (12.3)	90.1 (14.5)	86.5 (12.6)
Midweight, kg	64.9 (7.4)	65.5 (6.3)	56.8 (4.3)	62.9 (7.2)	56.9 (7.8)	56.6 (7.7)
Days fed	107.5 (4.2)	107.2 (3.7)	109.3 (3.4)	104.1 (1.0)	102.9 (3.3)	104.8 (2.5)
Intake, kg	259 (42.4)	239 (19.8)	199 (18.5)	254 (25.3)	212 (31.6)	198 (31.6)
Intake/d, kg	2.41 (.34)	2.23 (.20)	1.82 (.16)	2.44 (.25)	2.06 (.28)	1.89 (.28)
Intake$\cdot d^{-1}\cdot$midweight^{-1}, kg	.037	.034	.032	.039	.036	.033
Intake restriction	100	91.9	86.5	100	92.3	84.6

intake treatment. The greatest total weight gain was made by index barrows on the AP level of feeding, but because they were heavier at the start of the trial, midweight was greatest for index barrows on the AP91 level of intake.

Composition of the Test Pigs. The weights of fractions A, C and D were heavier for index barrows than for control barrows (table 5), due largely to heavier final weights for the index line. However, viscera weight (fraction B) was slightly less for the index line, although the difference was not significant.

Index barrows had significantly less fat in each fraction than did control barrows. They also had significantly more water in fractions A, B and C and more water in fraction D (carcass bone and cartilage), although the difference was not significant. Index barrows also had significantly more protein in fractions B, C and D than did control barrows. The percentage of protein in fraction A, however, was similar for both lines.

The index selection effectively improved carcass merit. The percentage of lean (water, protein and ash) in the edible portion of the carcass (fraction C) was 5.47 ± 1.12% higher for index barrows. Significant line differences existed for each component, except ash, when expressed as a percentage of whole body weight (table 6). Index barrows had 3.63 ± .71% less fat and 3.87 ± .71% more lean in the whole body than control barrows. The improvement in percentage lean tissue was made up mostly of water, but there was also a significant line difference for protein percentage (.70 ± .17%).

Restricting intake significantly reduced final weight and consequently, the weight of each fraction was reduced (table 5). However, the effect of restricting intake was greater for the weight of fraction C (edible carcass lean and fat) than for the weight of other body fractions. Contrast 2 compares the average of AP and AP91 feeding levels with the AP82 level. The higher daily feed intakes caused significantly higher fat percentages in the viscera (fraction B) and in the carcass lean and fat tissue (fraction C). The fat percentage was also higher in fraction A. The higher daily feed intakes also resulted in a significantly lower protein percentage in fraction C and significantly lower water percentages in fractions B and C. The differences between AP and AP91 feeding levels (contrast 3) were significant for fat and water percentage in fraction B and for percentage of fat, protein and water in fraction C. Compared

TABLE 5. LINE BY FEEDING LEVEL MEANS AND CONTRASTS AMONG MEANS FOR COMPOSITION OF TEST BARROWS

Trait[a]	Residual SD	Index select line			Control line			Contrast[b]		
		AP	AP91	AP82	AP	AP91	AP82	C_1	C_2	C_3
Number		8	8	7	10	10	10			
Fraction A										
Weight, kg	3.51	24.2	24.2	21.4	21.7	20.8	20.6	2.23 ± .97*	1.73 ± 1.05	.45 ± 1.18
Fat, %	3.85	36.2	34.9	33.2	37.5	36.3	36.4	−1.93 ± 1.07†	1.43 ± 1.15	1.25 ± 1.29
Protein, %	1.42	14.6	15.4	14.9	15.2	14.9	15.3	−.17 ± .39	−.08 ± .42	−.25 ± .48
Water, %	2.67	45.3	45.6	45.8	43.6	44.3	44.0	1.60 ± .74*	−.20 ± .80	−.50 ± .90
Ash, %	1.47	2.5	3.1	3.4	2.5	2.9	2.8	.27 ± .41	−.35 ± .44	−.50 ± .49
Fraction B										
Weight, kg	1.82	12.3	12.0	10.8	13.0	11.7	12.7	−.77 ± .50	.47 ± .54	.80 ± .61
Fat, %	5.22	25.3	22.4	19.1	29.9	24.7	23.4	−3.73 ± 1.45**	4.33 ± 1.56**	4.05 ± 1.75*
Protein, %	1.66	11.2	11.2	11.8	9.9	9.9	10.0	1.47 ± .46**	−.35 ± .49	.00 ± .56
Water, %	4.55	58.2	60.5	62.3	54.3	58.8	59.3	2.87 ± 1.26*	−2.85 ± 1.36*	−3.40 ± 1.53*
Ash, %	1.24	2.3	2.5	3.0	2.9	2.4	3.5	−.33 ± .34	−.73 ± .37†	.15 ± .42
Fraction C										
Weight, kg	7.40	54.4	52.1	41.8	51.6	44.6	41.6	3.50 ± 2.05†	8.98 ± 2.21**	4.65 ± 2.48†
Fat, %[c]	4.13	32.1	27.3	26.4	37.7	33.9	30.8	−5.53 ± 1.15**	4.15 ± 1.23**	4.30 ± 1.40**
Protein, %[c]	.90	13.6	14.3	14.6	12.5	13.4	14.0	.87 ± .25**	−.85 ± .27**	−.80 ± .30**
Water, %[c]	3.23	53.3	57.0	57.6	48.9	52.0	54.3	4.33 ± .90**	−3.15 ± .96**	−3.40 ± 1.08**
Ash, %[c]	.30	.8	1.1	1.2	.6	.6	.7	.40 ± .08**	.18 ± .09†	−.15 ± .10
Fraction D										
Weight, kg	1.20	9.9	10.4	8.9	9.1	8.7	8.9	.83 ± .33*	.63 ± .36†	.30 ± .40
Fat, %[c]	1.98	22.2	22.3	23.3	22.7	21.8	22.7	.20 ± .55**	−.75 ± .59	.05 ± .66
Protein, %[c]	1.48	17.2	17.5	17.8	18.2	18.3	17.8	4.73 ± .41**	.00 ± .44	−.20 ± .50
Water, %[c]	3.19	44.3	44.4	43.9	42.5	43.0	43.0	1.37 ± .89	.10 ± .95	−.30 ± 1.07
Ash, %[c]	2.12	14.3	13.9	13.3	15.2	15.4	14.6	−1.23 ± .59*	.75 ± .63	.10 ± .71

[a]Fraction A = blood, head, skin, hair and hooves; fraction B = viscera; fraction C = carcass edible lean and fat and fraction D = carcass bone and cartilage and unseparable fat and lean.

[b]C_1 = Index select line − control line, averaged over feeding levels.
C_2 = ½(AP + AP91) − AP82, averaged over lines.
C_3 = AP − AP91, averaged over lines.

[c]Initial body weight included in model as a covariate.

†$P<.10$.

*$P<.05$.

**$P<.01$.

TABLE 6. LINE BY FEEDING LEVEL MEANS AND CONTRAST AMONG MEANS FOR WHOLE BODY COMPOSITION OF THE TEST BARROWS

Trait	Residual SD	Index select line AP	Index select line AP91	Index select line AP82	Control line AP	Control line AP91	Control line AP82	Contrast[a] C_1	Contrast[a] C_2	Contrast[a] C_3
		%								
Fat[b]	2.55	31.6	27.9	27.0	35.1	32.2	30.1	−3.63 ± .71**	3.15 ± .76**	3.30 ± .86**
Protein[b]	.60	13.9	14.6	14.7	13.3	13.7	14.1	.70 ± .17**	−.53 ± .18**	−.55 ± .20**
Water[b]	2.22	50.9	53.4	53.6	47.9	49.9	51.4	2.90 ± .62**	−1.98 ± .66**	−2.25 ± .74**
Ash[b]	.30	2.7	3.1	3.2	2.7	2.9	3.1	.10 ± .08	−.30 ± .09**	−.30 ± .10**
Lean[b]	2.55	67.5	71.1	71.6	64.0	66.6	68.7	3.87 ± .71**	−2.85 ± .58**	−3.10 ± .86**

[a] C_1 = Index select line − control line, averaged over feeding levels.
C_2 = ½(AP + AP91) − AP82, averaged over lines.
C_3 = AP − AP91, averaged over lines.
[b] Initial body weight included in model as a covariate.
** $P < .01$.

with the AP intake level, the 91% regimen significantly reduced the percentage of fat and increased the percentage of water in fractions B and C. The percentage of protein in fraction C was also higher for pigs on the AP91 feeding level.

No interactions of feeding level × line were significant for the percentage of components in any fraction or in the whole body. The general effect of daily restrictions of feed intake was to significantly reduce the percentage of fat and to increase the percentage of lean (protein, water and ash) in the body (table 6). The first level of restriction, AP91 vs AP, caused the percentage body fat to decrease by 3.7 and 2.9% in index and control pigs, respectively. The second level of restriction, AP82 vs AP91, caused the percentage body fat to decrease by .9% in index pigs and by 2.1% in control pigs. Lines that differ in rate and composition of growth probably are affected differently by different daily feed intake restrictions. However, the numbers in this experiment were not sufficient to detect significant interactions of this magnitude.

The lower percentage of fat in index pigs gave them a higher body water to fat ratio than control pigs (1.86 ± .04 vs 1.58 ± .04). Also, the fat to protein ratio was smaller for index than for control pigs (2.02 ± .05 vs 2.39 ± .05). The general effect of restricting feed intake was to increase the ratio of water to fat (1.51, 1.84 and 2.10 for AP, AP91 and AP82, respectively) and decrease the ratio of fat to protein (2.47, 2.14 and 2.01, respectively). Neither feeding level nor selection background significantly influenced the ratio of water to protein, which ranged from 3.60 for control barrows on AP intake to 3.68 for index barrows on AP intake.

Daily Gain of Components. Daily gains of fat, protein, water, ash and lean in the body and in the carcass fat and lean tissue are presented in table 7. Average daily gain and probe backfat are also presented.

Index pigs had less probe backfat and higher daily gains than control pigs. They deposited significantly less fat and more water and protein per day.

Restricting daily feed intake significantly reduced daily fat gain, which was reduced similarly by intake restrictions from AP to AP91 and AP91 to AP82. However, in both lines the daily gain of protein, water and lean was only slightly reduced when daily feed intake was restricted from the AP to the AP91

TABLE 7. LINE BY FEEDING LEVEL MEANS AND CONTRASTS AMONG MEANS FOR AVERAGE DAILY GAIN, PROBE BACKFAT AND DAILY GAIN OF COMPONENTS OF BODY COMPOSITION

	Residual	Index select line			Control line			Contrast[a]		
Item	SD	AP	AP91	AP82	AP	AP91	AP82	C_1	C_2	C_3
Probe backfat, cm	.31	2.48	2.44	2.27	3.00	2.64	2.71	−.39 ± .09**	.15 ± .09†	.20 ± .10
Avg daily gain, g[b]	68	770	704	590	705	645	562	51 ± 19**	130 ± 20**	63 ± 23**
Whole body, g										
Fat[b]	28	264	210	175	277	233	194	−18 ± 8*	62 ± 8**	49 ± 9**
Protein	10	98	96	78	85	81	74	11 ± 3**	14 ± 3**	3 ± 3
Water	41	343	331	269	290	280	258	38 ± 11**	48 ± 12**	11 ± 14
Ash	3	19	20	18	18	18	17	1 ± .8	1 ± .9	−1 ± 1.00
Lean	51	461	449	366	393	379	349	52 ± 14**	63 ± 15**	13 ± 17
Fraction C, g										
Fat[b]	21	153	115	92	167	135	104	−15 ± 6*	45 ± 6**	35 ± 7**
Protein	7	57	54	43	47	45	39	8 ± 2**	8 ± 2**	3 ± 2
Water	25	218	210	167	183	172	150	30 ± 7**	37 ± 7**	10 ± 8
Ash	1.2	3.6	4.2	3.8	2.4	2.2	1.7	1.8 ± .3**	0.4 ± .4	−.2 ± .4
Lean	32	278	269	214	232	219	190	40 ± 9**	48 ± 10**	11 ± 11

[a] C_1 = Index select line − control line, averaged over feeding levels.
C_2 = ½(AP + AP91) − AP82, averaged over lines.
C_3 = AP − AP91, averaged over lines.

[b] Initial body weight included in model as a covariate.

† $P<.10$.

* $P<.05$.

** $P<.01$.

level. However, the index line exhibited a marked decline in daily gain of protein, water and lean when fed at the AP82 level.

Discussion

Index selection for average daily gain, measured over the interval of 56 d to 79 kg, and probe backfat thickness at 79 kg increased the rate of growth from 83 to 188 d of age and resulted in more lean and less fat in market weight barrows. Ollivier (1977), Sather and Fredeen (1978) and Vangen (1979) also have reported that index selection for increased average daily gain and decreased backfat was effective. The general results of these four experiments are similar, but the relative change per generation in the component traits differs somewhat among experiments. This may be explained in part by different relative weightings on the component traits and by different testing procedures. The lines from this experiment differed in percentage body fat by 3.6%. In contrast, after eight generations of index selection, Sundstøl et al. (1979) reported that fat and lean growth lines differed by 6% in fat.

Cote and Wangsness (1978) observed that lean and obese pigs differed in fat to protein ratio. Similarly, the index select and control lines of this study differed in water to fat and fat to protein ratios. However, selection did not alter the ratio of water to protein. In accordance with the results presented by Lawrie (1974), the water content of lean tissue declined with age. The water to protein ratio in the body was 4.33 at 83 d of age and 3.65 at 188 d of age. In the edible fat and lean tissue of the carcass, this ratio declined from 4.38 at 83 d to 3.93 at 188 d of age.

Restricting daily feed intake reduced average daily gain, decreased backfat thickness and improved composition of market weight barrows. Similar results have been reported by several other researchers (Hellberg, 1961; Vanschoubroek et al., 1967; Trapnell et al., 1978).

Although interactions were not significant, the index and control lines tended to respond differently to intake restrictions. Restrictions of feed intake caused similar reductions in both lines in daily fat deposition. However, line differences in protein and water gain were more pronounced for pigs fed the AP or AP91 feeding levels than for those fed the AP82 level. Daily protein intakes were calculated and compared with recommended levels (NRC, 1979). Daily protein intakes were adequate for all pigs except those fed the AP82 level. Select and control pigs on the AP82 regimen received approximately 88 and 93%, respectively, of estimated daily protein requirement. The index line was leaner and should have had a higher protein requirement. Inadequate daily protein intakes should have had a greater effect on the daily rate of protein synthesis and lean deposition in fast-growing, lean lines than in slower-growing, fatter lines. Also, the energy intake on the AP82 feeding level may have been so low that some dietary proteins were being catabolized for energy.

Index selection for rapid average daily gain and decreased backfat is effective for improving rate and composition of growth. An important question is whether or not the rate of improvement could be increased if some measure of feed intake were included in the selection index. M. Ellis and W. C. Smith (unpublished data) reported that selection on an index of average daily gain, backfat and food conversion ratio improved composition, but not rate of growth.

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