

Comparison of 1980 and Modern Swine Genetic Types when Reared on 1980 and Modern Swine Feeding Programs^{1,2}

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Introduction

The U.S. pork industry maintains profitability largely through continued improvement in productivity and cost control; however, producing high quality pork products is also important in maintaining consumer confidence. Phenotypic improvements have been reported in USDA data (National Pork Board, 2005) since 1955 for increasing lean mass and reproductive rates of pigs. This study was designed to document for most traits of economic interest, the relative contribution that genetic selection and enhancements in feeding programs have made to achieving improvements observed over the last 25 years.

Studies have been conducted in the poultry industry that evaluated the contributions of genetics and nutrition to improvements observed in growth performance and carcass composition (Havenstein et al, 1994a; Havenstein et al, 1994b; Havenstein et al, 2003a; Havenstein et al, 2003b). In addition, these researchers have reported on changes in immune response for these broilers (Qureshi et al, 1994; Cheema et al, 2003). They concluded that genetics, nutrition, and other management changes over the last 44 years have resulted in a broiler that requires approximately one-third the time and over a threefold decrease in the amount of feed consumed to produce a 1,815-g broiler. These data indicate that genetic selection by commercial breeding companies has brought about 85 to 90% of the change that has occurred in broiler growth rate and carcass composition over the past 45 yr. Nutrition has provided 10 to 15% of the changes observed.

Recently, Schwab et al. (2006) reported on the effect of long term selection for increased leanness on pork quality in a study comparing purebred Duroc pigs sired by boars representing the 1980s with pigs sired by boars representing the current time period. They found that pigs sired by old time period boars had superior pork quality and concluded that long-term selection for leanness has been at the expense of pork quality. They reported that loins from pigs sired by old time period boars had greater intramuscular fat and visual marbling scores, required less Instron force to compress and had darker visual color scores when compared to loins from pigs sired by contemporary Duroc boars.

Materials and Methods

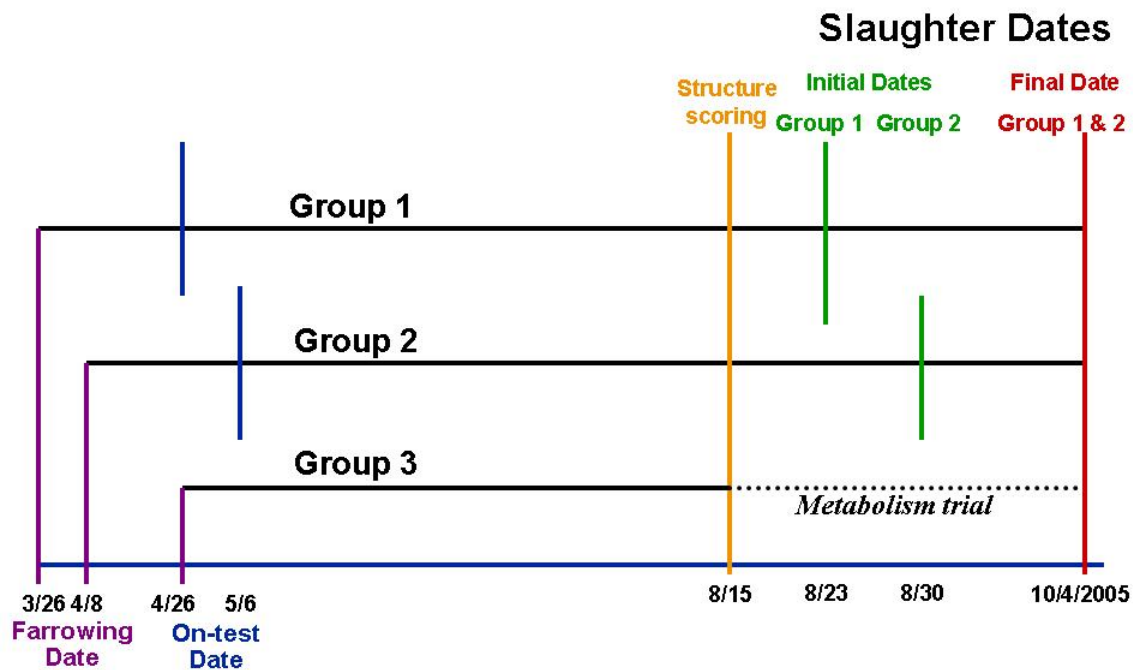
A control population for a genetic selection study of commercially available white line animals was formed in 1979 and has been maintained at NCSU since 1989. Fifteen first parity females from this unselected population were mated using frozen semen from Hampshire and Duroc boars that were commercially available in 1979 and 1980 producing twelve litters (7

¹ Prepared for the 2006 National Swine Improvement Federation Annual Meeting and Genetics Symposium, December 7th and 8th, Nashville, TN.

² This work was funded in part by the North Carolina Pork Council, North Carolina Agricultural Foundation, Murphy-Brown LLC, North Carolina Cooperative Extension Service, and North Carolina Agricultural Research Service.

Duroc sired and 5 Hampshire sired). Three Duroc and three Hampshire sires were represented. Pigs representative of 2005 commercial genetic lines of similar age to the 1980 genetic line pigs were obtained from a NC swine production company. Pigs were from three farrowing groups. Farrowing groups one, two, and three were included in evaluations of behavior and structure. Farrowing groups one and two were included in evaluations of growth performance, carcass composition, and muscle quality. Farrowing group three was used in a metabolism study evaluating nutrient utilization and odor. Figure 1 describes how the groups were used and the timeline associated with live animal portions of this study.

Figure 1. Experimental Design



Assessment of the nutritional contribution to changes in pig structure, growth, composition and quality was accomplished by placing one-half of the pigs from each genetic line on one of two feeding programs typical of those used in 1980 versus industry feeding practices common in 2005. Major differences in nutritional programs included diet formulation, meal diets versus pellets, no-antibiotics versus antibiotics, simple versus phased feeding program, and no synthetic amino acids versus synthetic amino acids. The 1980 feeding program consisted of four meal diets (lysine from 1.05 to 0.62% and ME from 3262 to 3317 Kcal/kg) based on formulations from the 1978 PIH (Table 1). The 2005 feeding was a seven phase feeding program (lysine from 1.51 to 0.73% and ME from 3428 to 3651 Kcal/kg), pelleted diets, and current diet formulation as used by NC producers (Table 2).

Table 1. 1980 Feeding Program

	<i>Prestarter</i>	<i>Starter</i>	<i>Grower</i>	<i>Finisher</i>
Crude Protein, %	18.3	17.9	15.0	13.3
Metabolizable Energy, kcal/kg	3262	3299	3315	3317
Calcium, %	0.87	0.78	0.67	0.67
Phosphorus, %	0.74	0.70	0.60	0.56
Lysine, %	1.05	0.95	0.75	0.62
Amount budgeted per pig, kg	11.3	15.9	90.7	to market

Table 2. 2005 Feeding Program

	<i>Prestarter</i>	<i>Starter</i>	<i>Starter</i>	<i>Grower</i>	<i>Grower</i>	<i>Finisher</i>	<i>Finisher</i>
		<i>1</i>	<i>2</i>	<i>1</i>	<i>2</i>	<i>1</i>	<i>2</i>
Crude Protein, %	22.6	22.3	22.1	17.9	16.9	14.7	12.0
Metabolizable Energy, kcal/kg	3428	3405	3438	3630	3643	3655	3651
Calcium, %	0.84	0.79	0.72	0.52	0.48	0.43	0.39
Phosphorus, %	0.72	0.68	0.64	0.55	0.47	0.41	0.37
Lysine, %	1.51	1.43	1.36	1.22	1.13	0.94	0.73
CTC, g	400	400	400	400	-	-	-
Denaguard, g	35	35	35	-	-	-	-
Tylan, g	-	-	-	-	20	-	-
Stafac, g	-	-	-	-	-	10	5
Amount budgeted per pig, kg	4.54	9.07	13.61	18.1	45.4	56.7	to market

A factorial design was used to compare pigs representative of 1980 commercial genetics and 2005 commercial genetics when fed feeding programs representative of 1980 and 2005 (Table 3). Pigs (n = 162) were reared at the North Carolina Swine Evaluation Station (Clayton, NC) and assigned to pens (3 pigs per pen) in a 2 x 2 x 2 factorial design for the growth and carcass portion of the study at approximately 7 kg BW. Pigs were housed on solid concrete floors with 5.6 m² per pen and provided ad libitum access to feed and water. All animal procedures were approved by the Institutional Animal Care and Use Committee of North Carolina State University.

Table 3. Experimental design and number of pens (pigs) per treatment

	<i>1980</i>		<i>2005</i>	
	<i>Barrows</i>	<i>Gilts</i>	<i>Barrows</i>	<i>Gilts</i>
Feeding Program				
1980	6 (18)	7 (21)	7 (21)	7 (21)
2005	5 (15)	8 (24)	7 (21)	7 (21)

Pigs were weighed at the start, end, and every two weeks throughout the study. Feeding programs were provided according to a budget (Tables 1 and 2) and feed allotments were weighed daily to determine ADG, ADFI, and G:F. Average daily gain, ADFI and G:F were calculated for on-test to nursery (OTN) (26.9 ± 0.7 kg), nursery to slaughter (NS) and on-test to slaughter (OTS). Fat depth and loin muscle area were measured by real-time ultrasound beginning at week four (Group 1) or five (Group 2) and measured every four weeks thereafter resulting in three measurements. Loin muscle area and backfat were adjusted to 45 kg (1), 70 kg (2) and 95 kg (3). Lean ADG (LADG), lean G:F (LG:F) and ADFI were calculated for on-test to slaughter (OTS) and first real-time ultrasound to slaughter (FSS).

Aggression was evaluated in all pigs ($n = 187$). Each pig was tested twice with tests being one week apart. Resident intruder tests were conducted by dividing pens in half and moving a resident pig into the empty half. An intruder pig was then introduced. Attack latency was recorded as time from when an intruder pig entered the pen until an attack occurred. Attack latencies were summed for the two tests. If no attack occurred then latency was 180 seconds. A resident-intruder score was given for the number of attacks (0, 1, or 2) during the two tests.

Structural correctness and mobility was scored on all pigs ($n = 187$) on one day (Figure 1). The three evaluators utilized a scoring system based on the Pocket Guide for the Evaluation of Structural, Feet, Leg and Reproductive Soundness in Replacement Gilts (Stalder et al., 2005). Front and rear legs were scored on a 1 to 5 scale; 1 = excessive set to the joints, 3 = ideal and 5 = extreme straightness in the joints. Front and rear view structure was scored from 1 to 3; 1 = toes out, 2 = ideal, and 3 = toes in. Mobility scores were from 1 to 5; 1 = severely impaired due to injury, 3 = ideal, and 5 = severely impaired due to structure.

Pigs were slaughtered by pen on a weekly basis when average pen weight exceeded 116 kg during August - October 2005. Slaughter data was collected at a commercial abattoir (Bailey Slaughterhouse, Bailey NC). At slaughter hot carcass weight and 45 minute pH were measured and viscera and liver samples collected. At 24 h post-mortem carcass length, fat depth at the 1st rib, 10th rib, last rib and last lumbar was measured, as well as, loin muscle area, marbling score, firmness score, Minolta color and ultimate pH. Primal cuts were separated and weighed and color, firmness, and wetness scored on the ham face, as well as, Minolta color. In addition, belly thickness and length was measured. A comparison test of belly firmness (stick test) was conducted by measuring the distance between the outside edges of the belly draped across a pipe. A loin, belly and ham from each pig was collected and frozen for chemical and sensory analysis as well as for evaluation of further processing. Fat samples were collected from the belly, loin and ham of each pig for analysis of fatty acid composition.

Percentage drip loss was estimated by hanging duplicate, 100g loin sections removed from between the 9th and 10th rib in a bag for 48 h postmortem. The loin sections were then reweighed and purge loss was determined. Warner Bratzler shear force was measured on cooked loin samples. Chemical analysis (University of Illinois, Champaign IL) of loin samples was conducted to determine percentage fat and moisture.

Sensory evaluations of loin samples were conducted by both consumer (100 consumers) and trained panels (6 members). Panelists were screened, selected and trained according to the standards of the American Society of Testing Materials (ASTM) STP 750 (1981) and the methods of Caul (1957) and Cairncross and Sjoström (1950). Trained flavor and texture descriptive panels were conducted on a 16 point intensity scale.

One-half of two pigs randomly selected from each pen was ground and sub-sampled for whole body composition and samples frozen. This included separate samples from the carcass,

viscera, and head. In addition, weights of individual organs were measured and stomachs were scored for incidence of gastric ulcers on a 1 to 7 scale. A liver sample was collected from each pig, DNA extracted and genotyped (GeneSeek Inc, Lincoln NE) for HAL 1843 and Rendement Napole (RN) mutation by DNA tests. All pigs in the study were normal (NN) for HAL 1843. For RN 39 pigs from the 1980 genetic line and 8 pigs from the 2005 genetic line were identified as carriers (rn^+RN^+). Analysis of whole body composition from these samples is underway.

An additional twenty-seven pigs (Group 3) were reared in the same 2 x 2 x 2 design in pens of either 3 or 4 and subsequently placed individually in metabolism crates at the Grinnell's Research Facility (Raleigh, NC) to evaluate nutrient digestion, nutrient excretion, and odor over two-week periods. Full urinary and fecal excretion was collected, sub-sampled and frozen for subsequent analysis. Chemical analysis of excreta and odor panel evaluations are underway.

Results and Discussion

Aggression

Genetic line and sex were both found to be significant for attack latency ($P < 0.03$ and $P < 0.04$, respectively) and resident intruder score ($P < 0.05$ and $P < 0.01$). On average, pigs from the 2005 genetic line attacked 22 seconds faster and 0.20 more times than 1980 genetic line pigs. Gilts attacked 22 seconds faster and 0.27 more times than barrows. Commercial pigs from 2005 were more aggressive toward a foreign pig than commercial pigs from 1980. One interpretation of these results is that selection for increased lean growth rate has resulted in correlated changes in behavior.

Structural Correctness

Pigs from the 2005 genetic line were more relaxed ($P < 0.01$) in their front leg joints than pigs from the 1980 genetic line. A Genetic line x sex interaction ($P < 0.01$) was observed where gilts from the 1980 genetic line were the straightest in their front leg joints. 1980 genetic line pigs were straighter ($P < 0.01$) in their rear leg joints than 2005 genetic line pigs. A feeding program by sex interaction ($P < 0.01$) indicated barrows fed the 1980 feeding program were more in at their hocks than pigs fed the 2005 feeding program. Based on a genetic line x feeding program interaction ($P < 0.01$) pigs from the 2005 genetic line fed the 1980 feeding program were the most mobile. Pigs from the 2005 genetic line were more ($P < 0.01$) mobile than 1980 genetic line pigs and pigs fed the 1980 feeding program were more ($P < 0.05$) mobile than pigs fed the 2005 feeding program. Results are summarized in Table 4.

Genetic improvement has occurred in structural correctness and mobility; however, changes in feeding program have resulted in reduced mobility. The improvement via genetics could have come from either direct selection placed on poorer structured individuals or through indirect selection which results from poorer structured individuals having less longevity in the herd and therefore less genetic influence. The reduction in mobility is possibly due to the fact the pigs are heavier muscled and faster growing.

Table 4. Effect of Genetic Line and Feeding Program on Structural Correctness

<i>Genetic line</i> <i>Feeding</i> <i>program</i>	<i>1980</i>		<i>2005</i>		<i>G*FP</i>	<i>Genetic</i> <i>line</i>	<i>Feeding</i> <i>program</i>
	<i>1980</i>	<i>2005</i>	<i>1980</i>	<i>2005</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
Front front	1.85 ^a	1.86 ^a	1.90 ^a	1.82 ^a	0.2336	0.8820	0.3415
Front side	3.27 ^{ab}	3.45 ^a	3.13 ^b	3.16 ^b	0.3325	0.0081	0.1913
Rear rear	1.36 ^a	1.44 ^a	1.42 ^a	1.42 ^a	0.2588	0.6386	0.3059
Rear side	3.53 ^a	3.40 ^{ab}	3.27 ^b	3.35 ^b	0.1053	0.0109	0.8026
Mobility	3.73 ^a	3.68 ^{ab}	3.35 ^c	3.56 ^b	0.0030	<0.0001	0.0469

^{a-c}Least squares means with no common superscript differ ($P < 0.05$)

Growth and Performance

The following growth data are summarized in Table 5. Pigs did not differ between treatments for on-test weight (7 ± 0.4 kg). Pigs from the 2005 genetic line had lower ($P < 0.01$) ADFI and a higher ($P < 0.01$) G:F for OTN than pigs from the 1980 genetic line. Pigs fed the 2005 feeding program had higher ($P < 0.01$) ADG and G:F for OTN than pigs fed the 1980 feeding program. For NS pigs from the 2005 genetic line had higher ($P < 0.01$) ADF and G:F than pigs from the 1980 genetics line. Pigs fed the 2005 feeding program for NS and OTS had higher ($P < 0.01$) ADG, lower ($P < 0.01$) ADFI and then higher ($P < 0.01$) G:F than pigs fed 1980 feeding program. Pigs from the 2005 genetic line had higher ($P < 0.01$) ADG and G:F than pigs from the 1980 genetic line during OTS. Genetic line x feeding program interactions were observed for NS and OTS ADG where 1980 genetic line pigs versus 2005 genetic line pigs showed 7.01% and 11.83% increases in NS ADG and 6.67% and 12.34% increases in OTS ADG when fed 1980 feeding program versus 2005 feeding program. Slaughter weight (119 ± 1.01 kg) did not differ for genetic lines or feeding program. However pigs from the 2005 genetic line and pigs fed the 2005 feeding program were younger ($P < 0.01$) at slaughter than pigs from the 1980 genetic and pigs from the 1980 feeding program

Lean Gain

Genetic line x feeding program interaction ($P < 0.01$) was observed where pigs from the 1980 genetic line and pigs from the 2005 genetic line had an increase in OTS ADG of 7.00% and 17.06% when fed 1980 feeding program versus 2005 feeding program. 2005 genetic line pigs had higher ($P < 0.01$) LADG for OTS and FSS, did not differ in ADFI for either and subsequently had higher ($P < 0.01$) LG:F for OTS and FSS than pigs from 2005 genetic line. Pigs fed the 2005 feeding program had higher ($P < 0.01$) LADG OTS, lower ($P < 0.01$) ADFI OTS and FSS and as a result has higher ($P < 0.01$) LG:F OTS and FSS. Data are summarized in table 5.

Table 5. Effect of Genetic Line and Feeding Program on Growth and Performance

<i>Genetic line</i> <i>Feeding</i> <i>program</i>	<i>1980</i>		<i>2005</i>		<i>G*FP</i>	<i>Genetic</i> <i>line</i>	<i>Feeding</i> <i>program</i>
	<i>1980</i>	<i>2005</i>	<i>1980</i>	<i>2005</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
On-test to nursery							
ADG, kg	0.4795 ^a	0.5338 ^b	0.4349 ^a	0.5435 ^b	0.0975	0.2859	<0.0001
ADFI, kg	0.9356 ^a	0.8877 ^{ab}	0.811 ^b	0.8301 ^b	0.2893	0.0055	0.6464
Gain:Feed	0.52 ^a	0.60 ^b	0.54 ^a	0.66 ^c	0.1514	0.0011	<0.0001
Nursery to slaughter							
ADG, kg	0.8526 ^a	0.9121 ^b	0.9255 ^b	1.0419 ^c	0.0495	<0.0001	<0.0001
ADFI, kg	2.6815 ^a	2.3876 ^b	2.5903 ^{ac}	2.4607 ^{bc}	0.0908	0.8499	<0.0001
Gain:Feed	0.32 ^a	0.38 ^b	0.36 ^c	0.42 ^d	0.9824	<0.0001	<0.0001
On-test to slaughter							
ADG, kg	0.7513 ^a	0.7989 ^b	0.7879 ^b	0.8851 ^c	0.0406	<0.0001	<0.0001
ADFI, kg	2.2076 ^a	1.9358 ^b	2.0913 ^c	1.9466 ^b	0.0795	0.1265	<0.0001
Gain:Feed	0.3402 ^a	0.4124 ^b	0.3785 ^c	0.4554 ^d	0.6001	<0.0001	<0.0001
Lean gain, on-test to slaughter							
Lean ADG, kg	0.2332 ^a	0.2495 ^b	0.2656 ^c	0.3109 ^d	0.0045	<0.0001	<0.0001
ADFI, kg	2.2076 ^a	1.9385 ^b	2.0913 ^c	1.9466 ^b	0.0795	0.1265	<0.0001
Lean gain:feed	0.11 ^{ab}	0.13 ^a	0.13 ^b	0.16 ^{ab}	0.0708	<0.0001	<0.0001
Lean gain, first scan to slaughter							
Lean ADG, kg	0.2483 ^a	0.2503 ^a	0.3128 ^b	0.3341 ^c	0.2146	<0.0001	0.1354
ADFI, kg	2.8826 ^a	2.5464 ^b	2.8328 ^{ac}	2.6885 ^{bc}	0.0853	0.4034	<0.0001
Lean gain:feed	0.09 ^a	0.10 ^b	0.11 ^c	0.13 ^d	0.8431	<0.0001	0.0002
Slaughter							
Slaughter age, d	177.64 ^a	169.16 ^b	170.11 ^b	154.61 ^c	0.0760	<0.0001	<0.0001
Slaughter wt, kg	118.37 ^a	118.94 ^b	119.21 ^c	119.33 ^d	0.7525	0.3856	0.6301

^{a-d}Least squares means with no common superscript differ ($P < 0.05$)

Realtime Ultrasound

Pigs from the 2005 genetic line were leaner ($P < 0.01$) at each ultrasound measurement time and had a larger ($P < 0.01$) loin muscle area for first two real-time ultrasound measurements than pigs from 1980 genetic line. Pigs fed 2005 feeding program had larger ($P < 0.01$) loin muscle area for all three real-time ultrasound measurements but did not differ for backfat. Data summarized in table 6.

Genetic improvement led to increases in ADG, leanness, loin muscle area and thus improved the overall lean gain. Changes in feeding programs led to improvements in ADG and loin muscle area, reduced ADFI and as a result improved overall lean gain.

Table 6. Effect of Genetic Line and Feeding Program on Real-time ultrasound BF and LMA

<i>Genetic line</i> <i>Feeding program</i>	<i>1980</i>		<i>2005</i>		<i>G*FP</i> <i>P-value</i>	<i>Genetic line</i> <i>P-value</i>	<i>Feeding program</i> <i>P-value</i>
	<i>1980</i>	<i>2005</i>	<i>1980</i>	<i>2005</i>			
^d BF1, cm	1.18 ^a	1.28 ^a	1.00 ^b	1.03 ^b	0.3931	<0.0001	0.1033
^d LMA1, cm ²	17.99 ^a	19.45 ^b	18.20 ^a	20.38 ^b	0.4196	0.2008	0.0001
BF2, cm	1.79 ^a	1.81 ^a	1.45 ^b	1.51 ^b	0.7772	<0.0001	0.4272
LMA2, cm ²	26.20 ^a	28.28 ^b	27.29 ^{ab}	30.76 ^c	0.1267	0.0003	<0.0001
BF3, cm	2.34 ^a	2.50 ^a	1.93 ^b	2.03 ^b	0.7045	<0.0001	0.1043
LMA3, cm	34.29 ^a	36.39 ^b	36.69 ^b	40.27 ^c	0.2102	<0.0001	<0.0001

^{a-c}Least squares means with no common superscript differ ($P < 0.05$)

^dThe numeral 1, 2 or 3 following the train acronym refers to the ultrasound measurement taken.

Carcass Traits

Carcasses were heavier ($P < 0.01$) but shorter ($P < 0.01$) for pigs fed 2005 feeding program compared to pigs fed 1980 feeding program. Dressing percent for pigs fed 2005 feeding program was higher ($P < 0.05$). Pigs fed the 2005 feeding program had thicker ($P < 0.05$) bellies on the loin side but shorter ($P < 0.05$) and less firm ($P < 0.01$) (as measured by the bellystick) bellies than pigs fed 1980 feeding program. 2005 genetic line pigs had firmer ($P < 0.05$) (as measured by the bellystick) than pigs from 1980 genetic line pigs. All carcass measurements for loin muscle area and backfat were adjusted to 85 kg. Genetic line x feeding program interaction ($P < 0.05$) where 2005 (15.40%) genetic line pigs and 1980 (8.2%) genetic line pigs had larger loin muscle area when fed 2005 feeding program versus 1980 feeding program. Pigs from 2005 genetic line were leaner at first rib ($P < 0.05$), 10th rib ($P < 0.01$) and last lumbar ($P < 0.01$) than pigs from 1980 genetic line. Pigs fed 1980 feeding program were leaner at first rib ($P < 0.01$) and last rib ($P = 0.05$) than pigs fed 2005 feeding program.

Table 7. Effect of Genetic Line and Feeding Program on Carcass Measurements

<i>Genetic Line</i> <i>Feeding program</i>	<i>1980</i>		<i>2005</i>		<i>G*FP</i> <i>P-value</i>	<i>Genetic line</i> <i>P-value</i>	<i>Feeding program</i> <i>P-value</i>
	<i>1980</i>	<i>2005</i>	<i>1980</i>	<i>2005</i>			
Carcass length, cm	87.01 ^a	85.27 ^b	87.07 ^a	85.04 ^b	0.7338	0.8590	0.0004
Dressing %	73.03 ^{ab}	73.64 ^a	72.4 ^b	73.81 ^a	0.2733	0.5755	0.0225
HCW, kg	84.88 ^a	87.31 ^b	85.42 ^a	88.05 ^b	0.8960	0.4429	0.0062
LMA, cm ²	36.84 ^a	39.87 ^b	42.73 ^c	49.31 ^d	0.0355	<0.0001	<0.0001
BF 10 th rib, cm	3.19 ^a	3.30 ^a	2.51 ^b	2.41 ^b	0.2486	<0.0001	0.9390
BF 1 st rib, cm	3.99 ^a	4.34 ^b	3.73 ^c	4.09 ^{ab}	0.9557	0.0356	0.0064
BF last rib, cm	2.89 ^{ab}	3.05 ^a	2.72 ^b	2.92 ^{ab}	0.7458	0.0821	0.0535
BF last lumbar, cm	2.56 ^a	2.62 ^a	2.27 ^b	2.45 ^{ab}	0.2967	0.0013	0.0866

^{a-c}Least squares means with no common superscript differ ($P < 0.05$)

Table 8. Effect of Genetic Line and Feeding Program on Trimmed Belly Measurements

<i>Genetic line</i>	<i>1980</i>		<i>2005</i>		<i>G*FP</i>	<i>Genetic line</i>	<i>Feeding program</i>
<i>Feeding program</i>	<i>1980</i>	<i>2005</i>	<i>1980</i>	<i>2005</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
Thickness loin edge, cm	4.01 ^a	4.43 ^b	4.14 ^{ab}	4.35 ^{ab}	0.3988	0.8665	0.0429
Thickness teat edge, cm	3.25 ^a	3.53 ^a	3.41 ^a	3.63 ^a	0.8401	0.4117	0.1433
Thickness ham end, cm	3.63 ^a	3.75 ^a	3.66 ^a	3.88 ^a	0.8211	0.7070	0.4641
Thickness shoulder end, cm	4.90 ^a	4.78 ^a	5.24 ^a	4.75 ^a	0.3389	0.4544	0.1708
Stick test, cm	33.66 ^a	20.96 ^b	27.81 ^c	19.63 ^b	0.1281	0.0320	<0.0001
Belly length, cm	53.84 ^a	52.32 ^a	53.52 ^a	51.80 ^a	0.8653	0.5307	0.0285

^{a-c}Least squares means with no common superscript differ ($P < 0.05$)

Genetic improvement has increased muscling, leanness and belly firmness. Changes in nutrition has improved muscling and dressing percent but has resulted in pigs with shorter carcasses that are fatter and have reduced belly firmness.

Pork Quality

Loin and ham quality data are summarized in Tables 9 and 10. Loins from pigs fed 1980 feeding program had higher ($P < 0.01$) 45 minute pH. Genetic line x feeding program interactions ($P < 0.05$) were observed for percentage intramuscular fat and visual marbling scores in the loin muscle where 2005 genetic line pigs fed the 1980 feeding program had the highest visual marbling score and greatest percent intramuscular fat. Both subjective marbling score and percent intramuscular fat for the loin muscle were higher ($P < 0.01$) for pigs from the 2005 genetic line versus pigs from the 1980 genetic line and pigs fed the 1980 feeding program versus pigs fed the 2005 feeding program. Drip loss percentage measured on loin muscle samples also showed similar results; less ($P < 0.05$) drip loss was observed for 2005 genetic line pigs and pigs fed the 1980 feeding program. Warner Bratzler shear force measured on cooked pork loin samples was more ($P < 0.05$) desirable for 1980 genetic line pigs compared to 2005 genetic line pigs. Ham pH measured 24 hour postmortem and ham subjective wetness score were higher ($P < 0.05$) for pigs fed 1980 versus 2005 feeding program. Hams from 1980 genetic line pigs were more ($P < 0.05$) red (Minolta a) and more ($P < 0.01$) blue (Minolta b) than those from 2005 genetic line pigs.

Table 9. Effect of Genetic Line and Feeding Program on Loin Muscle Quality.

<i>Genetic line</i>	<i>1980</i>		<i>2005</i>		<i>G*FP</i>	<i>Genetic line</i>	<i>Feeding program</i>
<i>Feeding program</i>	<i>1980</i>	<i>2005</i>	<i>1980</i>	<i>2005</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
pH ⁴⁵	6.28 ^{ac}	6.13 ^b	6.28 ^a	6.10 ^{bc}	0.7657	0.7766	0.0107
pH ^u	5.69 ^{ab}	5.66 ^{ab}	5.74 ^a	5.60 ^b	0.2090	0.9953	0.0924
Marbling, subjective	1.71 ^a	1.44 ^a	2.85 ^b	1.74 ^a	0.0110	0.0002	0.0006
% IMF	0.0420 ^a	0.0300 ^b	0.0625 ^c	0.0342 ^{ab}	0.0189	0.0019	<0.0001
Firmness, subjective	2.49 ^{ab}	2.31 ^a	2.65 ^b	2.41 ^{ab}	0.7978	0.2546	0.0869
Wetness, subjective	2.55 ^a	2.43 ^a	2.57 ^a	2.58 ^a	0.5103	0.4537	0.6906
Color, subjective	2.30 ^{ab}	2.20 ^a	2.56 ^b	2.38 ^{ab}	0.7531	0.1447	0.3802
Minolta L	53.22 ^a	52.14 ^a	53.20 ^a	52.42 ^a	0.7673	0.8167	0.1227
Minolta a	9.39 ^{ab}	9.38 ^{ab}	10.06 ^a	8.93 ^b	0.0913	0.7512	0.1395
Minolta b	6.45 ^a	6.26 ^a	6.76 ^a	6.24 ^a	0.4734	0.5668	0.1971
Drip loss, %	0.029 ^a	0.035 ^a	0.022 ^b	0.029 ^{ab}	0.9462	0.0195	0.0347
WBS, kg	2.93 ^a	2.76 ^b	2.90 ^a	3.05 ^a	0.0022	0.0255	0.8099

^{a-c}Least squares means with no common superscript differ ($P < 0.05$)

Table 10. Effect of Genetic Line and Feeding Program on Ham Quality.

<i>Genetic line</i>	<i>1980</i>		<i>2005</i>		<i>G*FP</i>	<i>Genetic line</i>	<i>Feeding program</i>
<i>Feeding program</i>	<i>1980</i>	<i>2005</i>	<i>1980</i>	<i>2005</i>	<i>P-value</i>	<i>P-value</i>	<i>P-value</i>
pH ⁴⁵	5.96 ^a	5.89 ^a	5.88 ^a	5.97 ^a	0.1705	0.9772	0.8554
pH ^u	5.83 ^{ab}	5.72 ^a	5.89 ^b	5.69 ^a	0.3679	0.7407	0.0144
Wetness, subjective	2.02 ^{ab}	1.84 ^{ba}	2.31 ^b	1.62 ^a	0.1010	0.8458	0.0166
Firmness, subjective	2.18 ^a	2.05 ^a	2.41 ^a	2.23 ^a	0.9017	0.3091	0.4788
Color, subjective	2.73 ^a	2.77 ^a	2.90 ^a	2.64 ^a	0.4604	0.9086	0.6484
Minolta L	50.52 ^a	50.33 ^a	49.82 ^a	50.25 ^a	0.6572	0.6158	0.8913
Minolta a	11.03 ^{ab}	11.54 ^a	10.65 ^b	10.23 ^b	0.1575	0.0226	0.9062
Minolta b	4.13 ^{ab}	4.61 ^a	3.56 ^b	3.67 ^b	0.4151	0.0051	0.2863

^{a-c}Least squares means with no common superscript differ ($P < 0.05$)

Genetic improvement appears to have had favorable affects on intramuscular fat and water holding capacity in the loin muscle. Changes in nutrition have reduced loin muscle intramuscular fat and water holding capacity along with reducing loin and ham pH.

Eating Quality

Ratings from a consumer sensory evaluation and trained flavor and descriptive panels for pork loin chops are summarized in tables 11 and 12. Loin samples from pigs fed the 1980 feeding program tended to have a higher ($P < 0.09$) flavor liking and a more ($P < 0.08$) intense juiciness than loin samples from pigs fed 1980 feeding program. Texture liking was higher ($P = 0.05$) for samples taken from pigs fed the 1980 versus 2005 feeding program. Overall liking for pork loin samples was higher ($P < 0.01$) from pigs fed 1980 feeding program than pigs fed 2005 feeding program. The difference between 1980 and 2005 genetic line did not appear to affect any of the eating qualities measured in this consumer panel.

Table 11. Effect of Genetic Line and Feeding Program on Consumer Sensory Analysis for Pork Loin Chops

<i>Genetic line</i> <i>Feeding program</i>	<i>1980</i>		<i>2005</i>		<i>G*FP</i> <i>P-value</i>	<i>Genetic</i> <i>line</i> <i>P-value</i>	<i>Feeding</i> <i>program</i> <i>P-value</i>
	<i>1980</i>	<i>2005</i>	<i>1980</i>	<i>2005</i>			
Overall liking	6.05 ^a	5.49 ^b	5.94 ^a	5.65 ^{ab}	0.4001	0.9195	0.0081
Flavor liking	5.89 ^a	5.46 ^a	5.79 ^a	5.63 ^a	0.4181	0.8364	0.0840
Juice intensity	4.24 ^{ab}	3.82 ^a	4.39 ^b	4.14 ^{ab}	0.6624	0.2007	0.0717
Texture liking	5.68 ^a	5.17 ^b	5.76 ^a	5.59 ^{ab}	0.3414	0.1521	0.0510
Tenderness intensity	4.23 ^{ab}	4.03 ^a	4.55 ^b	4.21 ^{ab}	0.6975	0.1723	0.1499

^{a-c}Least squares means with no common superscript differ ($P < 0.05$)

Cooked pork aroma was stronger ($P < 0.01$) in loin samples from pig fed the 1980 feeding program. Loin samples from pig fed 2005 feeding program had a higher ($P = 0.02$) cohesive mass score than samples from pigs fed 1980 feeding program. There was genetic line x feeding program interaction ($P < 0.01$) for cooked pork flavor where loin samples from 1980 genetic line pigs fed 1980 feeding program versus 2005 feeding program did not differ but loin samples from 2005 genetic line pigs had more cooked pork flavor when fed 2005 feeding program versus 1980 feeding program. Genetic line x feeding program interactions were observed where loin samples from 2005 genetic line pigs did not differ when fed 1980 feeding program versus 2005 feeding program, however loin samples from 1980 genetic line pigs fed 2005 feeding program were juicier ($P < 0.01$) and had more moisture release ($P < 0.01$) than loin samples from pigs fed 1980 feeding program. Also genetic line x feeding program interactions were observed where loin samples from 2005 genetic line pigs were harder ($P < 0.01$) and more fibrous ($P < 0.01$) when fed 2005 feeding versus 1980 feeding program while loin samples from 1980 genetic line pigs fed 1980 feeding program versus 2005 feeding program were harder ($P < 0.01$) and more fibrous ($P < 0.05$).

Table 12. Effect of Genetic Line and Feeding Program on Trained Flavored and Descriptive Panels for Pork Loin Chops

<i>Genetic line</i> <i>Feeding program</i>	<i>1980</i>		<i>2005</i>		<i>G*FP</i>	<i>Genetic</i>	<i>Feeding</i>
	<i>1980</i>	<i>2005</i>	<i>1980</i>	<i>2005</i>	<i>P-value</i>	<i>line</i> <i>P-value</i>	<i>program</i> <i>P-value</i>
Cooked pork aroma	3.50 ^a	3.39 ^a	3.67 ^b	3.37 ^a	0.0557	0.1022	<0.0001
Cooked pork flavor	4.77 ^a	4.87 ^{ab}	4.97 ^b	4.81 ^a	0.0037	0.1080	0.4783
Piggy	0.00 ^a	0.00 ^a	0.00 ^a	0.00 ^a	0.3162	0.3162	0.3162
Metallic	1.54 ^a	1.57 ^a	1.62 ^a	1.61 ^a	0.6347	0.0568	0.7595
Astringent MF	1.53 ^a	1.52 ^a	1.54 ^a	1.53 ^a	0.9774	0.6099	0.5902
Oxidized	0.00 ^a	0.02 ^a	0.00 ^a	0.00 ^a	0.3162	0.3162	0.3162
Sweet	1.57 ^a	1.59 ^a	1.61 ^a	1.56 ^a	0.0743	0.9532	0.4816
Salt	0.48 ^a	0.50 ^a	0.54 ^a	0.48 ^a	0.4237	0.5871	0.6010
Sour	1.78 ^a	1.77 ^a	1.78 ^a	1.84 ^a	0.2687	0.2777	0.4607
Bitter	0.00 ^a	0.01 ^a	0.00 ^a	0.00 ^a	0.3184	0.3184	0.3184
Hardness	7.07 ^a	6.63 ^b	6.62 ^b	7.28 ^a	<0.0001	0.2663	0.2462
Moisture RLS	3.65 ^a	4.02 ^b	3.76 ^a	3.67 ^a	0.0021	0.0988	0.0550
Cohess mass	6.51 ^b	6.28 ^a	6.47 ^{ab}	6.33 ^{ab}	0.5386	0.9462	0.0200
Juicy	4.10 ^a	4.36 ^b	4.14 ^a	3.99 ^a	0.0018	0.0124	0.4222
Fibrous	5.38 ^a	5.21 ^b	5.21 ^b	5.47 ^a	0.0004	0.4698	0.4894
Oily MCT	0.56 ^a	0.57 ^a	0.59 ^a	0.58 ^a	0.3591	0.2026	0.8755
# of Chews	35.94 ^{ab}	34.71 ^a	34.98 ^a	37.63 ^b	0.0042	0.1456	0.2873

^{a-c}Least squares means with no common superscript differ ($P < 0.05$)

Changes in genetics do not appear to have affected eating quality traits for pork loin chops either negatively or positively. However, nutritional changes appear to have led to poorer eating quality traits as measured by consumer sensory analysis but not the trained flavor and descriptive panels for pork loin chops.

Conclusion

Overall the pork industry has made advances in traits of economic interest through genetic selection and improved feeding practices. Improvement in growth rate is due to equal contributions from genetics and feeding programs while observed improvements in efficiency were primarily due to changes in feeding practice. However, improved carcass composition is primarily a result of genetic improvement. Pork quality characteristics have been improved by genetic selection but this did not result in measurable improvements in eating quality. Changes in feeding practices over the last 25 years have had negative impacts on measures of pork quality and consumer preference.

These results provide the pork industry a greater understanding of industry changes and provide documentation that can be used with the general public and regulatory groups on positive developments that have occurred. In addition, the results of this study provide data that

can be used to develop future research studies to investigate the underlying biological mechanisms associated with the observed changes.

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