Direct and Correlated Responses to Selection for Intramuscular Fat in Duroc Swine

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Summary and Implications

At the present state of technology, intramuscular fat percentage can be accurately evaluated in live pigs and utilized in conjunction with sib carcass data for estimation of breeding values for intramuscular fat. Within the population under study, selection on resulting EBV has yielded a significant phenotypic change in all measures of IMF. Phenotypic gain in IMF established through selection in the current study resulted in IMF levels that may be useful for differentiation of sire lines for use in muscle quality-based niche markets. Results from this study illustrate that phenotypic improvement of IMF may correspond to an increase in objective tenderness, and shed light into the possible ramifications of this response in measures of carcass composition. Intramuscular fat may be used in swine breeding programs as an indicator of general product palatability; however, sensory characteristic improvements are likely to be slow when simultaneous improvement in other trait categories is also pursued.

Introduction

It is becoming increasingly apparent that the swine industry should strengthen its focus on the production of uniform, high quality products. Intramuscular fat (IMF) percentage is receiving greater attention in breeding programs due to its implicated role in consumer acceptance. Until recently, identification of genetically superior breeding stock for IMF was limited to use of sib and progeny testing. However, recent developments in real-time ultrasound technology have allowed accurate prediction of IMF in the live animal. The development of optimal selection criteria requires knowledge of expected correlated responses among other economically important traits. In order to study the responses to selection for IMF, a large-scale selection experiment involving purebred Duroc swine was initiated in 1998. The primary objective of this investigation was to evaluate the efficacy of selection for IMF as determined by direct phenotypic response. A second objective was to determine correlated phenotypic effects in other economically important traits.

Materials and Methods

Using semen from Duroc boars available in regional U.S. boar studs, 2 generations of random mating were conducted to expand the population and produce the base generation of 56 litters. Littermate pairs of gilts from the base generation were randomly designated to either the control (CL) or select line (SL). Littermate pairs of females were then mated to the same boar (via natural mating or AI) to establish sufficient genetic ties between lines before selection was initiated. At weaning, up to 4 boars in each SL litter (when available) were randomly selected to remain intact to increase selection intensity. The number of observations through 6 generations is presented by line in Table 1.

Off-test ultrasonic measurements of 10^{th} rib LM area (ULMA), off-midline backfat (UBF), and intramuscular fat percentage (UIMF) were collected at a mean live weight of 110 (±14) kg. Ultrasonic images were collected with an Aloka 500V SSD ultrasound machine. Final image parameters were generated using texture analysis software and were included in a regression equation to estimate intramuscular fat percentage.

Standard carcass collection procedures were followed to obtain carcass composition and meat quality measurements on all available barrows and randomly selected gilts within each generation after harvest at Hormel foods, Austin, MN. A section of bone-in loin containing the 10^{th} to 12^{th} ribs was removed from the carcass and transported to the Iowa State University Meat Laboratory for 48 hr measures of meat quality. A 3.2 mm slice from the 10^{th} rib face was removed and utilized for percent lipid content analysis (CIMF). Water holding capacity was measured on the 11th rib face using the filter paper method described by Kauffman et al. (1986).

A trained sensory panel with 3 members evaluated cooked loin quality attributes on the 11^{th} rib section. Three 1.3 cm^3 cubes were removed from the center of the 11th rib sample and evaluated by the trained sensory panel for juiciness, tenderness, chewiness, flavor, and off-flavor using an end-anchored, 10-point scoring system (AMSA, 1995). Sample evaluations were averaged across panelists for analysis. The 12th rib section was evaluated for tenderness using an Instron Universal Testing Machine (model 1122; Instron Corp., Canton, MA).

Breeding values within each generation were estimated for predicted (UIMF) and carcass (CIMF) intramuscular fat by fitting a 2-trait animal model that included fixed effects of sex and contemporary group and random common environmental (birth litter) and animal genetic effects. Selection was based on EBV for CIMF. In the select line, the 10 boars and 75 gilts with the highest EBV were selected. Inbreeding coefficients of individuals and all possible matings among selection candidates were calculated with the use of the INBREED procedure of SAS. This information was utilized to design matings in both lines in an attempt to minimize inbreeding accumulation.

Average inbreeding coefficients for progeny in generation 6 were 4.8% and 9.5% for the control and select lines, respectively.

Line differences in generation 6 were assessed using the MIXED procedure of SAS. The final model used to compute LS means and corresponding standard errors included fixed effects of line, sex, contemporary group, and the interaction of line and sex. An appropriate linear weight covariate was also included when significant along with random effects of sire nested within line and dam nested within sire and line.

Results and Discussion

Through 6 generations of selection, an 88% improvement in IMF has been realized (4.53% in SL vs. 2.41% in CL). The phenotypic response realized for CIMF coincides with a slightly smaller phenotypic response in UIMF observed after 6 generations of selection. No significant differences ($P > 0.05$) were observed between lines for growth performance, whether measured as the number of days required to reach 114 kg of BW (DAYS), daily accumulation of BW (ADG), or daily accretion of lean tissue (LGOT). These results suggest that breeding programs aimed solely at improvement of IMF, should not expect large correlated changes in growth.

Results of this study revealed significant correlated responses in various measures of carcass composition (Table 2). A difference of 6.17 mm greater backfat measured ultrasonically at the tenth rib ($P < 0.01$) was found in the SL, similar in magnitude to the difference detected on the carcass at the same location ($P < 0.01$) in a random sample of pigs harvested. A smaller line effect was also found for carcass measures at the last thoracic (CLRBF) and last lumbar (CLLBF) vertebrae. The SL had less loin muscle area ($P < 0.01$) when compared to the CL, whether measured on the carcass of harvested pigs or predicted ultrasonically on the live animal.

The direct response in IMF corresponded to a correlated increase ($P < 0.01$), similar in magnitude, in subjective marbling score. However, subjective measures of firmness and color were not significantly different between lines. Also, no significant correlated responses were observed in the current study for pH measured at 24 h, 48 h, or 7 d post-mortem.

The significant phenotypic response in IMF after 6 generations of selection has also resulted in an 8% increase ($P < 0.05$) in instrumental tenderness (Table 3). Water holding capacity and percent cooking loss are indicators of physical processing characteristics and were not significantly ($P > 0.54$) affected by selection in the present study. Objective measures of loin color were significantly affected by selection for increased IMF. Loin samples from harvested SL pigs were associated with 2.33% more light reflectance and a 2.41 unit increase in Hunter L value at 24 h post-mortem when compared to their unselected CL counterparts. It is important to note that this correlated response in loin color may be influenced by variation in exposed IMF and may not reflect true differences in the pigmentation of lean tissue.

A general trend for more desirable sensory scores was observed for the SL within the current study; however, statistically significant ($P < 0.05$) differences were only detected for measures of pork flavor intensity and incidence of off-flavor (Table 4).

Table 1. Distribution of records by generation and line from a selection experiment for increased intramuscular fat in Duroc swine.

	Generation						
Trait category	**1**	**2**	**3**	**4**	**5**	**6**	**Total**
	No. of observations						
Select line							
Litters	45	56	54	75	63	60	353
Growth and ultrasound meas.	291	379	373	484	373	344	2,244
Carcass and sensory meas.	64	54	64	77	70	72	401
Boars	75	119	123	182	128	118	745
Gilts	145	192	187	237	188	180	1129
Barrows	71	68	63	65	57	46	370
Control line							
Litters	50	36	38	50	58	47	279
Growth and ultrasound meas.	345	235	264	349	410	277	1,880
Carcass and sensory meas.	86	47	81	71	101	77	463
Boars	85	59	63	98	102	72	479
Gilts	181	124	128	168	201	138	940
Barrows	79	52	73	83	107	67	461
Total							
Litters	95	92	92	125	121	107	632
Growth and ultrasound meas.	636	614	637	833	783	621	4,124
Carcass and sensory meas.	150	101	145	148	171	149	864
Boars	160	178	186	280	273	190	1224
Gilts	326	316	315	405	389	318	2,069
Barrows	150	120	136	148	164	113	831

Table 2. Least squares means (±SE) for growth performance and carcass composition from generation 6 of a selection experiment for increased intramuscular fat in Duroc swine.

	Line		
Item	SL	CL	SL-CL
Growth performance			
Average daily gain, kg/d	0.78 ± 0.01	0.77 ± 0.01	0.02 ± 0.02
Lean gain on test, kg/d	0.22 ± 0.00	0.22 ± 0.00	0.00 ± 0.00
Days to 114 kg, d	189.54 ± 1.03	187.62 ± 1.15	1.93 ± 1.54
Ultrasound measures			
Scan backfat, mm	20.53 ± 0.58	14.35 ± 0.58	6.17 ± 0.80***
Scan loin muscle area, cm^2	39.15 ± 0.53	42.73 ± 0.54	-3.62 ± 0.72***
Predicted intramuscular fat, %	4.55 ± 0.10	3.09 ± 0.10	1.46 ± 0.14***
In-plant carcass composition			
Length, cm	81.94 ± 0.34	81.44 ± 0.33	0.50 ± 0.47
Tenth rib backfat, mm	24.22 ± 0.84	16.63 ± 0.87	7.59 ± 1.19***
Last rib backfat, mm	24.43 ± 0.66	18.78 ± 0.66	5.65 ± 0.90***
Last lumbar backfat, mm	19.38 ± 0.76	14.87 ± 0.75	4.51 ± 1.06***
Loin muscle area, cm^2	38.02 ± 0.77	45.45 ± 0.75	-7.43 ± 1.06***

***$P < 0.001$.

Table 3. Least squares means (±SE) for meat quality from generation 6 of a selection experiment for increased intramuscular fat in Duroc swine.

	Line		
Item[a]	SL	CL	SL-CL
Intramuscular fat, %	4.53 ± 0.25	2.41 ± 0.25	2.12 ± 0.35***
Subjective color	3.25 ± 0.07	3.11 ± 0.08	0.14 ± 0.10
Subjective marbling	4.89 ± 0.21	2.50 ± 0.21	2.39 ± 0.29***
Subjective firmness	2.16 ± 0.05	2.05 ± 0.05	0.11 ± 0.07
24 h pH	5.65 ± 0.01	5.65 ± 0.01	0.00 ± 0.01
24 h Minolta reflectance, %	24.49 ± 0.36	22.17 ± 0.36	2.33 ± 0.50***
24 h Hunter L value	49.42 ± 0.37	47.00 ± 0.37	2.41 ± 0.52***
48 h pH	5.63 ± 0.01	5.62 ± 0.01	0.01 ± 0.02
48 h Minolta reflectance, %	23.77 ± 0.36	22.40 ± 0.36	1.37 ± 0.50*
48 h Hunter L value	48.78 ± 0.58	46.89 ± 0.58	1.89 ± 0.80*
Water holding capacity, mg	67.43 ± 2.91	69.81 ± 2.87	-2.38 ± 3.99
7 d pH	5.61 ± 0.01	5.60 ± 0.01	0.01 ± 0.02
Percent cooking loss, %	19.22 ± 0.41	18.87 ± 0.43	0.35 ± 0.58
Instron tenderness, kg	5.36 ± 0.15	5.81 ± 0.15	-0.45 ± 0.21*

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$.

[a]Subjective color score (1 = pale pinkish gray to white; 6 = dark purplish red); Subjective marbling score (1 = 1.0% intramuscular fat; 10 = 10.0% intramuscular fat); Subjective firmness score (1 = soft; 3 = very firm); Minolta reflectance values are objective measures of light reflectance (0 = 0% reflectance; 100 = 100% reflectance); Hunter L values are objective measures of exposed lean color (0 = black; 100 = white).

Table 4. Least squares means (±SE) for sensory panel evaluation from generation 6 of a selection experiment for increased intramuscular fat in Duroc swine.

	Line		
Item[a]	**SL**	**CL**	**SL-CL**
Juiciness score	6.59 ± 0.13	6.37 ± 0.13	0.22 ± 0.18
Chewiness score	2.94 ± 0.18	3.06 ± 0.18	-0.12 ± 0.25
Tenderness score	6.52 ± 0.21	6.35 ± 0.21	0.17 ± 0.29
Flavor score	2.80 ± 0.13	2.39 ± 0.13	0.41 ± 0.18*
Off-flavor score	2.38 ± 0.14	2.78 ± 0.15	-0.40 ± 0.20*

*$P < 0.05$.

[a]Trained sensory panel evaluations of juiciness (1 = dry; 10 = juicy), chewiness (1 = not chewy; 10 = very chewy), tenderness (1 = tough; 10 = tender), flavor (1 = little pork flavor, bland; 10 = extremely flavorful, abundant pork flavor), and off-flavor (1 = no off-flavor; 10 = abundant non-pork flavor).