The Effects of Long Term Selection for Reduced Backfat and Increased Loin Muscle Area on Meat and Eating Quality Traits in Duroc Swine

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Abstract

A study was conducted to evaluate differences in performance, carcass composition, and eating quality characteristics of pigs sired by purebred Duroc boars currently available and pigs sired by purebred Duroc boars from the mid 1980's. Two lines were developed by splitting and randomly allocating littermate and ½ sib pairs of females to matings by current (CTP) or old (OTP) time period boars. Subsequent boar, barrow, and gilt progeny from two replications were weighed on test at a group mean live weight of 140 lbs. Off-test ultrasonic LMA, BF10, and IMF measurements were collected on 789 pigs at a mean live weight of 240 lb. Records on pigs sired by CTP boars, from both replications (n=556), represented 23 sires while pigs sired by OTP boars (n=231) consisted of 15 sire groups. All available barrows and randomly selected gilts (n=277) were sent to a commercial abattoir and measurements of tenth-rib backfat (CBF10), last rib backfat (CLRBF), last lumbar backfat (CLLBF), and loin muscle area (CLMA) were collected. Chemical intramuscular fat percentage was determined by lab analysis of a loin sample from the 10^{th} rib face of the longissimus muscle. Additional meat and eating quality traits measured were: Minolta reflectance and Hunter L (24 and 48 h); pH (24 h and 7 d); water holding capacity; subjective visual scores for color, marbling, and firmness (48 h); Instron tenderness, cooking loss, and trained sensory panel evaluations (7 d). Six serial ultrasonic measurements of 10^{th} rib loin muscle area (LMA), off-midline backfat (BF10), and intramuscular fat percentage (IMF) from the first replication were collected every two weeks and used to assess deposition rate and growth pattern differences.

There was no significant difference in average daily gain of pigs sired by boars from the two time periods. Pigs sired by CTP boars had larger ($P < 0.05$) LMA measurements and less BF10, while pigs sired by OTP had significantly more IMF. Carcass evaluation revealed larger CLMA measurements, and significantly less CBF10, CLRBF, and CLLBF measurements for pigs sired by CTP boars. Pigs sired by OTP boars had a higher intramuscular fat percentage, lower Instron tenderness values, and higher subjective marbling and color scores than pigs sired by CTP boars ($P < 0.05$). There were no significant differences between time periods for Minolta reflectance, Hunter L (24 and 48 h), water holding capacity, pH (24 h and 7 d), and subjective firmness scores. Trained sensory evaluations revealed higher ($P < 0.05$) flavor scores and lower off-flavor scores for OTP sired pigs; however, no significant differences in tenderness score, juiciness score, chewiness score, and cooking loss were found between lines. Progeny of OTP boars began the test period at heavier weights and begin to decrease in daily body weight gain toward the conclusion of the test period, finishing with no advantage in body weight when compared to progeny of CTP boars. The analysis of serial backfat measurements revealed a linear pattern of backfat deposition between 150 and 270 lbs. Pigs sired by OTP boars deposited more backfat ($P <0.05$) at a significantly faster rate than pigs sired by CTP boars throughout the entire test period.

A curvilinear tissue deposition pattern was found for both LMA and IMF. Significant linear and quadratic regression coefficient differences between lines indicate that pigs sired by CTP boars deposit more LMA and less IMF per pound of live weight gain than pigs sired by OTP boars through the course of the test.

Introduction

Due to an increasingly volatile and competitive hog market, producers constantly struggle with the issue of how to maintain a pork industry that is economically viable. The initiation of grid-based marketing systems within the past 20 years has created an opportunity for producers to increase the value of the hogs they market through increased lean percentage. Prior to 1985, 90 percent of hogs marketed were sold as traditional 'commodity pork' where price was determined on a live weight basis (Hayenga et al., 1985). The utilization of incentive-based marketing systems became increasingly important to producers seeking to add value to the hogs they produced, corresponding to increased selection for lean percentage. As a result, the percentage of hogs sold on a carcass basis rose to 28 percent in 1988 and to 78 percent in 1997 (Brorsen et al., 1998).

In nearly 20 years, pork producers have made tremendous strides toward providing a leaner product to the packer, and ultimately, the consumer. However, through intensive selection for increased carcass leanness, the swine industry has allowed consumer acceptance issues to arise as a result of decreased meat quality. Quality characteristics that play an integral role in consumer acceptance, such as intramuscular fat, have decreased as breeders have intensely selected for increased leanness (Barton-Gade, 1990; Cameron, 1990).

Objectives

The objectives of this study were threefold. The primary objective was to quantify the effect that selection for decreased backfat thickness and increased loin muscle area (i.e. increased percent lean) has had on meat and eating quality traits and performance since the initiation of incentive-based hog pricing in the mid to late 1980's. The second objective of the study was to assess any changes in growth patterns of these traits that may have resulted from the marketing scheme changes during this time period. The final goal of the study was to identify boars or genetic lines from the 1980's with superior meat quality that maintain adequate growth and carcass composition in today's pork industry.

Materials and Methods

Two lines were formed by randomly allocating littermate and ½ sib pairs of Duroc females to matings by current (CTP) or old (OTP) time period boars. Matings by CTP Duroc boars were made using fresh semen and matings by OTP Duroc boars were made utilizing frozen semen. The Duroc breed was chosen due to its popularity as the terminal sire of choice, either purebred or in composite sire lines, throughout the world. The total number of pigs evaluated for each trait category is presented in Table 1.

Boars, gilts, and barrows in each line were weighed and ultrasonically evaluated for LMA, BF10, and IMF every two weeks beginning at a group mean live weight of 140 lbs. Serial ultrasonic images were collected with an Aloka 500V SSD ultrasound machine fitted with a 3.5 MHz, 12.5 cm linear-array transducer. Off-midline BF10 and LMA were measured from a cross-sectional image taken at the 10^{th} rib. A sound transmitting guide conforming to the pig's back was attached to the ultrasound probe and vegetable oil was used as conducting material between the probe and skin. A minimum of four longitudinal images were collected 3 in off-midline across the 10^{th} - 13^{th} ribs and a trained technician used texture analysis software (Amin et al., 1997) to estimate final IMF parameters. Ultrasonically measured IMF was predicted by the method of Newcom et al. (2002).

Mean live weights for each of the respective scans for the CTP and OTP pigs are presented in Table 2. After being weighed off test, all available barrows and randomly selected gilts (n=277) were sent to a commercial abattoir and measurements of tenth-rib backfat (CBF10), last rib backfat (CLRBF), last lumbar backfat (CLLBF), and loin muscle area (CLMA) were collected following a 24-hour chill. Ultimate pH was measured on the 10^{th} rib face of the longissimus muscle using a pH star probe (SFK Ltd., Hvidovore, Denmark). Hunter L (L24) and Minolta reflectance were measured on the 10^{th} rib face of the loin using a Minolta CR-310 (Minolta Camera Co., Ltd., Japan) with a 2 in-diameter aperture, D65 illuminant, and calibrated with a white calibration plate. Hunter L and Minolta values are measures of light reflectance where lower values indicate darker and more desirable color.

A section of bone-in loin containing the 10^{th} rib was removed from the carcass and transported to the Iowa State University Meat Laboratory, Ames. At 48 hours post-mortem, the 11^{th} and 12^{th} rib sections were sliced into one inch chops and allowed to bloom. Subjective measures of color (1-6), marbling (1-10), and firmness (1-3) were evaluated according to NPPC (2000) on the 11th rib face. Water holding capacity was measured on the 11th rib face by the filter paper method of Kauffman et al. (1986) and is reported in mg of water absorbed by the filter paper, so lower values are more desirable.

The 11th and 12th rib chops were taken to the Iowa State University Food Science Laboratory and refrigerated at 0º C for 7 d. A trained sensory panel with three members (Huff-Lonergan et al., 2002) evaluated cooked loin quality attributes. Chops were cooked to 71º C in an electric broiler (Amana model ARE 640, Amana, IA), with sample temperature monitored by Chromega/Alomega thermocouples attached to an Omega digital thermometer (DSS-650, Omega Engineering, Inc., Stamford, CT). Weights prior to and immediately after cooking were used to calculate percent cooking loss. Three 0.5 inch cubes were removed from the center of the 11th rib sample and evaluated by a trained sensory panel for juiciness (1 = dry and 10 = juicy), tenderness (1 = tough and 10 = tender), chewiness (1 = not chewy and 10 = very chewy), flavor (1 = little pork flavor or bland and 10 = extremely flavorful or abundant pork flavor), and off-flavor (1 = no off-flavor and 10 = abundant non-pork flavor) using an end anchored, 10-point scoring system. Sample evaluations were averaged across panelists for analysis. The 12th rib section was utilized for a final measure of pH and evaluated for tenderness using an Instron Universal Testing Machine (Model 1122; Instron Corp., Canton, MA) fitted with a circular, five-point star probe (nine mm diameter with six mm between points) (Oltrogge-Hammernick and Prusa, 1987).

To evaluate the effect of time period on growth performance, carcass composition, meat quality, and deposition rates, two types of analyses were utilized: phenotypic analysis of traits measured over the whole test period, and phenotypic analysis of traits measured serially. Time period differences for growth, carcass composition, meat quality, and sensory evaluation characteristics were assessed with the use of a mixed model that included fixed effects of time period, replication, sex, contemporary group, and the interaction of sex by time period. Sire and dam nested within time period were included as random effects. Traits that were measured serially were BW, BF, LMA, and IMF. A random regression model was fit to the serial data using SAS (SAS Inst. Inc., Cary, NC) to model the covariance between repeated records. The model used to evaluate growth patterns of serially measured traits included similar fixed effects to the model described previously along with the addition of fixed and random curves. Interactions of second order polynomial terms with time period were fit for the evaluations of BW, LMA, and IMF, while the interaction of a first order polynomial term with time period was fit for BF. A first order polynomial was fit for the random curve of BW, BF, LMA, and IMF. An unstructured covariance structure was fit for the random terms and an auto-regressive covariance structure was fit for residuals.

Results and Discussion

Least squares means and standard errors for average daily gain and carcass composition, as well as meat and eating quality traits are presented in Tables 3 and 4. There was no significant difference in average daily gain between pigs sired by Duroc boars from the two time periods. Pigs sired by CTP boars had more ($P < 0.05$) LMA and less BF10, while pigs sired by OTP boars had significantly more IMF. Carcass evaluation revealed more CLMA and significantly less CBF10, CLRBF, and CLLBF for pigs sired by CTP boars. Pigs sired by OTP boars had a higher intramuscular fat percentage, lower Instron tenderness values, and higher subjective marbling and color scores than pigs sired by CTP boars ($P < 0.05$). There were no significant differences between time periods for the evaluations of Minolta reflectance, Hunter L (24 and 48 h), water holding capacity, pH (24 h and 7 d), and subjective firmness score. Trained sensory evaluations revealed higher ($P < 0.05$) flavor scores and lower off-flavor scores for OTP-sired pigs; however, no significant differences in tenderness score, juiciness score, chewiness score, and percent cooking loss were detected between lines. Time period differences indicate that long-term selection for increased carcass leanness has generated a significant response in enhanced carcass composition; however, this increase has been at the expense of various meat and eating quality characteristics.

Least squares means and corresponding standard errors for LMA, BF10, and IMF at each of the respective scans are presented in Table 5. Graphic representations of the growth patterns for LMA, BF and IMF are illustrated in Figures 1-4. Though no significant difference between lines for ADG measured over the entire test period was found in this study, differences in body weight growth patterns were found. Progeny of OTP boars began the test period at heavier weights and begin to decrease in daily body weight gain toward the conclusion of the test period, finishing with no advantage in body weight when compared to progeny of CTP boars. The analysis of serial backfat measurements revealed a linear pattern of backfat deposition between 150 and 270 lbs. Pigs sired by OTP boars deposited more backfat ($P <.05$) at a significantly faster rate than pigs sired by CTP boars throughout the entire test period. Results of this study indicate that the long-term response to selection realized within the Duroc breed in terms of enhanced carcass leanness has established a difference in the deposition rates and patterns associated with tenth-rib backfat. A curvilinear tissue deposition pattern was found for both LMA and IMF. Significant linear and quadratic regression coefficient differences between lines indicate that pigs sired by CTP boars deposit more LMA and less IMF per pound of live weight gain than pigs sired by OTP boars through the course of the test. This study shows that long-term changes in carcass leanness have also yielded similar alterations in deposition patterns of correlated traits such as LMA and IMF.

Specific sire lines evaluated in this study have been identified for superior growth and performance as well as meat and eating quality traits. Preeminent OTP sires recognized for enhanced meat and eating quality characteristics while maintaining adequate growth and carcass composition indicate the efficacy of genetic archives currently maintained by boar studs and seedstock producers. These sires will be used to generate populations for further investigation of genetic improvement of meat and eating quality traits.

Implications

In order to remain competitive in the future, it is important that pork producers develop a way to differentiate their product. Fresh pork quality is continuing to become increasingly important and has received more attention as producers and processors try to meet consumer demand for high quality, nutritious products. Overcoming the issue of poor pork quality is an avenue that will enable producers to improve consumer acceptance of pork. By quantifying the effect that long-term intensive selection for increased carcass leanness has had on meat quality characteristics, we may begin to identify opportunities for producers to add value to the pork products they produce.

Results from this study have illustrated that significant progress toward the enhancement of carcass composition has been realized within the Duroc breed since the mid 1980's. These long-term changes have also altered the growth patterns and deposition rates of ultrasonically measured 10^{th} rib backfat, loin muscle area, and intramuscular fat. Unfortunately, the enhancement of carcass leanness over time has been at the expense of meat quality traits, namely intramuscular fat percentage, tenderness, and color, as well as eating quality traits such as flavor.

Identification of genetic lines that are available via frozen semen which have superior meat quality attributes and maintain adequate growth and carcass composition is facilitated with this study. Utilization of genetic lines offering superior meat quality may be utilized to diversify pork products when pursuing niche markets involving enhanced meat quality. This study also demonstrated that it is feasible to utilize genetic archives developed by seedstock producers and boar studs. Ultimately, findings of this study should enable packers and processors to further understand the long-term ramifications of grid-based pricing of hogs when little or no emphasis on meat quality is applied.

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Table 1. Distribution of records from a study comparing purebred Duroc pigs sired by boars from two time periods.

	Number of Observations				
Trait Category	**Total**	**Replication 1**	**Replication 2**	**CTP**	**OTP**
Deposition Rates[a]	422	422	0	298	124
Growth & Ultrasonic Meas.[b]	792	422	370	557	235
Carcass Composition[c]	277	132	145	178	99
Meat Quality[d]	277	132	145	178	99
Sensory Evaluation[e]	277	132	145	178	99

[a]Deposition rates for ultrasonically measured Loin Muscle Area, Backfat, and Intramuscular Fat Percentage
[b]Average Daily Gain; ultrasonically measured off-test Loin Muscle Area, Backfat, and Intramuscular Fat Percentage
[c]In-plant carcass measures of 10th Rib Backfat, Last Rib Backfat, Last Lumbar Backfat, and Loin Muscle Area
[d]Intramuscular fat percentage measured by lab analysis; Minolta Reflectance; Hunter L; pH; Water Holding Capacity; Visual Color, Firmness, and Marbling; Tenderness; Cooking Loss
[e]Sensory panel scores of Flavor, Off-flavor, Juiciness, Chewiness, Tenderness

Table 2. Mean live weights (lbs) of serial ultrasonic scans collected on purebred Duroc pigs sired by boars from two time periods.

	Scan Number					
Line	**1**	**2**	**3**	**4**	**5**	**6**
Current Time Period	132.0	156.9	182.7	209.6	230.3	243.1
Old Time Period	138.9	164.8	191.3	218.0	233.9	242.3

Table 3. Least squares means (±SE) for average daily gain and carcass composition for purebred Duroc pigs sired by boars from two time periods.

	Time Period	
Item[a]	**Current**	**Old**
Average Daily Gain, lb/d	1.87 ± 0.02	1.86 ± 0.03
Tenth-Rib Backfat, in	0.80 ± 0.02*	1.10 ± 0.03*
Last Rib Backfat, in	0.94 ± 0.02*	1.09 ± 0.02*
Last Lumbar Backfat, in	0.76 ± 0.02*	0.95 ± 0.02*
Loin Muscle Area, in^2	6.47 ± 0.09*	5.40 ± 0.11*

*LS means between time periods are significantly different ($P < 0.05$)
[a]Average Daily Gain calculated from test period; Carcass measures collected in-plant 24 hours post-mortem

Table 4. Least squares means (±SE) for meat and eating quality traits for purebred Duroc pigs sired by boars from two time periods.

	Time Period	
Item	**Current**	**Old**
Intramuscular Fat Percentage, %	3.09 ± 0.13*	3.48 ± 0.15*
Instron Tenderness, kg	5.98 ± 0.12*	5.31 ± 0.13*
Subjective Color Score (1-6)	3.87 ± 0.08*	4.09 ± 0.08*
Subjective Firmness Score (1-3)	2.08 ± 0.04	2.14 ± 0.04
Subjective Marbling Score (1-10)	3.07 ± 0.13*	3.54 ± 0.15*
24 hr. Minolta Reflectance, %	22.70 ± 0.31	23.25 ± 0.34
48 hr. Minolta Reflectance, %	21.40 ± 0.28	21.78 ± 0.32
24 hr. Hunter L Value, %	47.67 ± 0.32	48.10 ± 0.35
48 hr. Hunter L Value, %	46.20 ± 0.30	46.60 ± 0.33
48 hr. pH	5.77 ± 0.02	5.80 ± 0.02
7 day pH	5.65 ± 0.01	5.65 ± 0.01
Water Holding Capacity, mg	47.33 ± 2.31	47.75 ± 2.46
Percent Cooking Loss, %	19.09 ± 0.38	18.96 ± 0.42
Tenderness Score (1-10)	6.67 ± 0.19	7.19 ± 0.22
Flavor Score (1-10)	1.98 ± 0.10*	2.35 ± 0.11*
Off-Flavor Score (1-10)	3.08 ± 0.14*	2.63 ± 0.14*
Juiciness Score (1-10)	6.12 ± 0.15	6.18 ± 0.16
Chewiness Score (1-10)	2.52 ± 0.13	2.23 ± 0.15

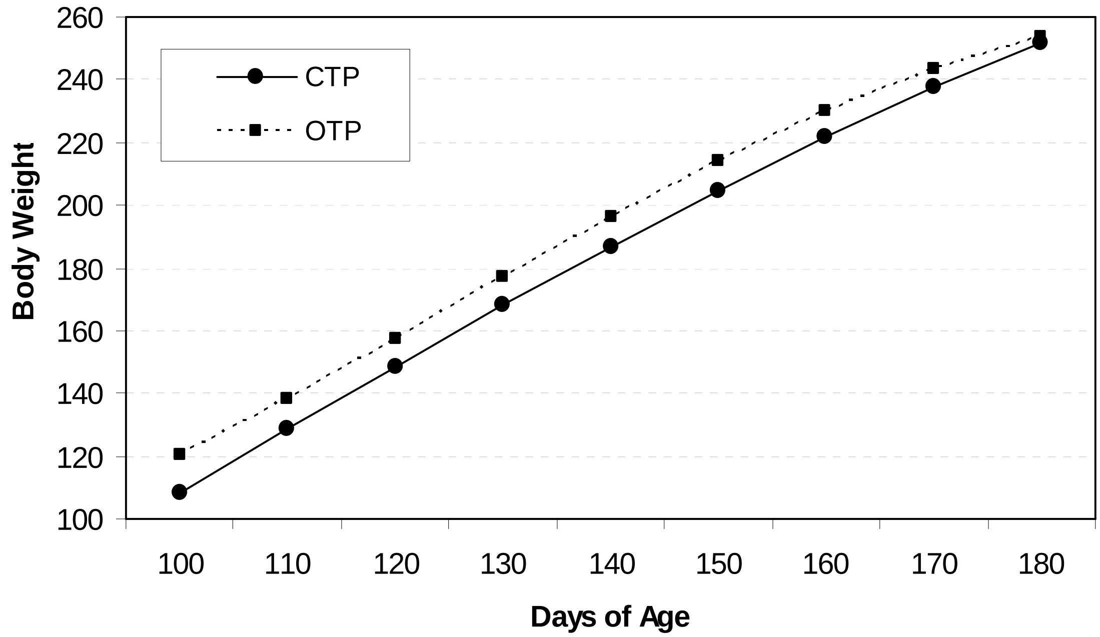
*LS means between time periods are significantly different ($P < 0.05$)

Table 5. Least squares means (±SE) of serial ultrasonic measures of loin muscle area, tenth rib backfat, and loin intramuscular fat percentage for purebred Duroc pigs sired by boars from two time periods.[a]

	Scan 1	**Scan 2**	**Scan 3**	**Scan 4**	**Scan 5**	**Scan 6**
LMA, in^2						
CTP[b]	3.83 ± 0.06	4.44 ± 0.06	4.98 ± 0.07	5.54 ± 0.09	6.04 ± 0.10	6.34 ± 0.18
OTP[c]	3.55 ± 0.08	3.87 ± 0.08	4.44 ± 0.09	4.95 ± 0.12	5.21 ± 0.12	5.51 ± 0.16
BF10, in						
CTP	0.52 ± 0.01	0.57 ± 0.02	0.65 ± 0.02	0.72 ± 0.02	0.72 ± 0.02	0.79 ± 0.04
OTP	0.59 ± 0.02	0.67 ± 0.02	0.79 ± 0.02	0.87 ± 0.03	0.95 ± 0.02	0.98 ± 0.04
IMF, %						
CTP	3.62 ± 0.07	3.56 ± 0.08	3.55 ± 0.08	3.95 ± 0.10	3.99 ± 0.10	4.04 ± 0.20
OTP	3.54 ± 0.10	3.64 ± 0.11	3.96 ± 0.10	4.33 ± 0.14	4.51 ± 0.12	4.59 ± 0.17

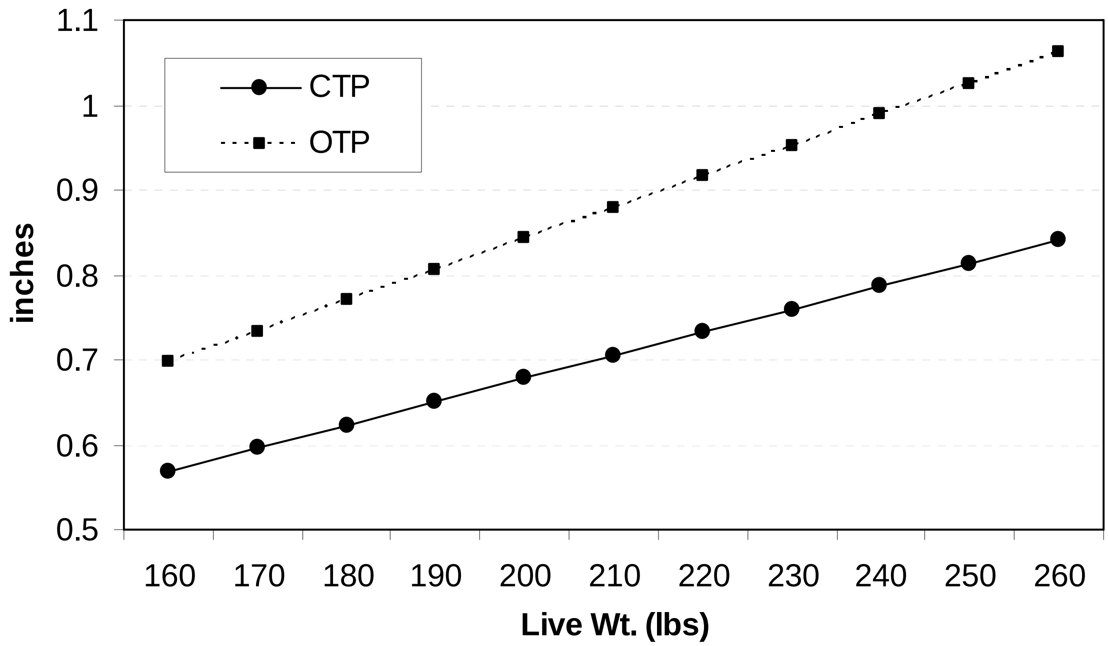
[a]LMA = Loin Muscle Area; BF = Backfat; IMF = Intramuscular Fat Percentage
[b]CTP = Current Time Period Duroc
[c]OTP = Old Time Period Duroc

Figure 1. Growth patterns of body weight change (lbs) with age for purebred Duroc pigs sired by boars from two time periods.



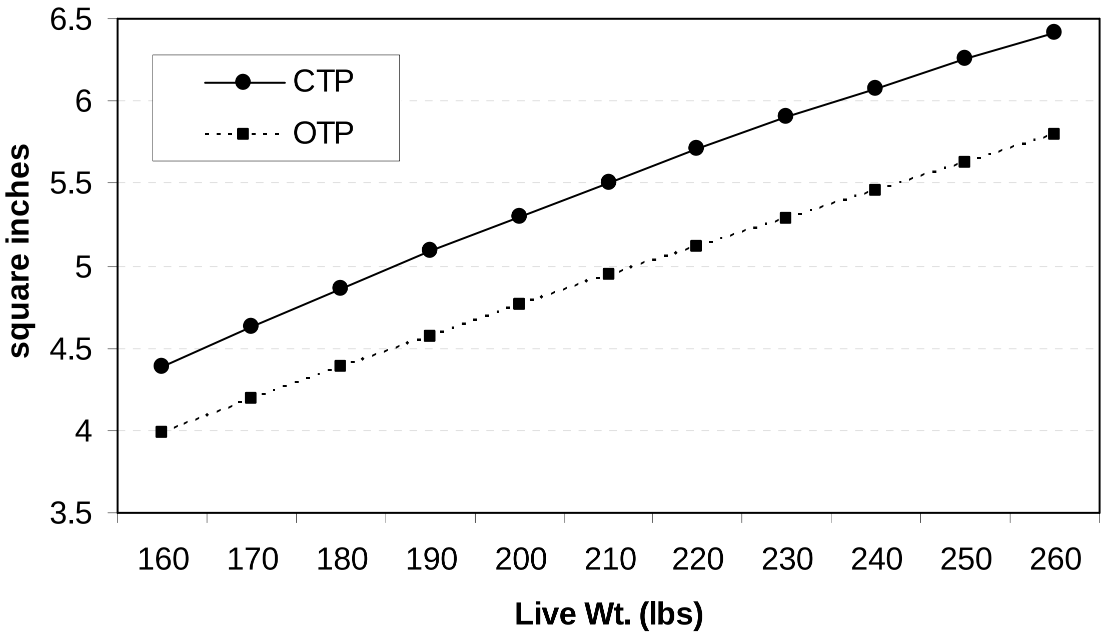
CTP = Current Time Period Duroc
OTP = Old Time Period Duroc

Figure 2. Growth patterns of tenth-rib backfat (in) from a study comparing purebred Duroc pigs sired by boars from two time periods.



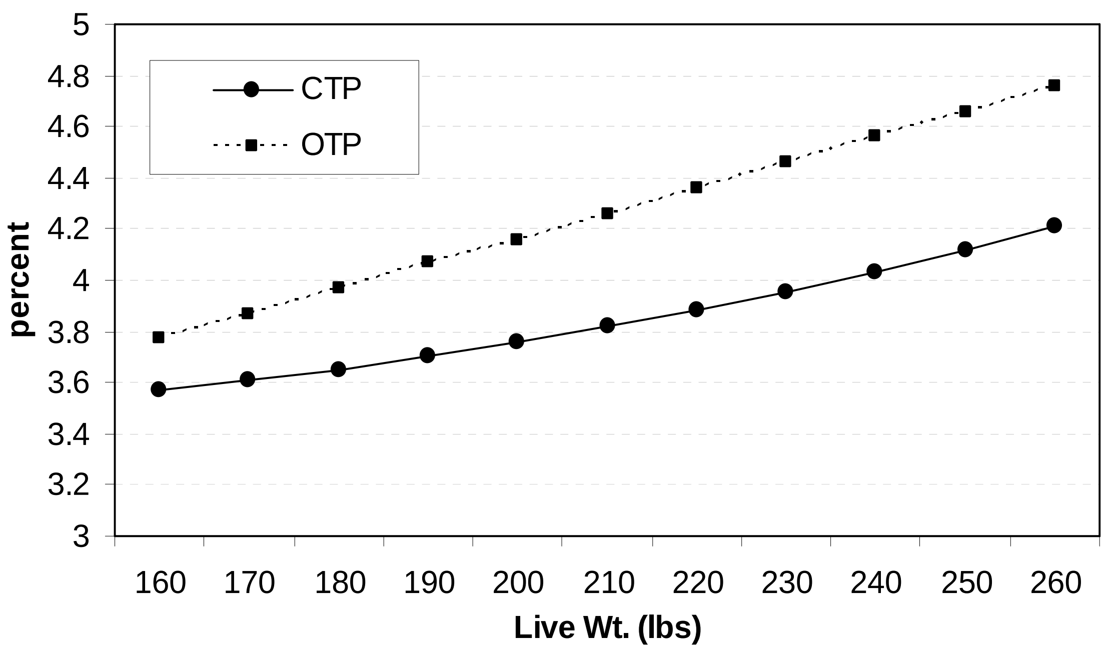
CTP = Current Time Period Duroc
OTP = Old Time Period Duroc

Figure 3. Growth patterns of loin muscle area (in^2) change with weight for purebred Duroc pigs sired by boars from two time periods.



CTP = Current Time Period Duroc
OTP = Old Time Period Duroc

Figure 4. Growth patterns of intramuscular fat percentage (%) change with weight for purebred Duroc pigs sired by boars from two time periods.



CTP = Current Time Period Duroc
OTP = Old Time Period Duroc