

**Comparison of carcass composition, performance, and tissue deposition rates among
breeds of swine**

by

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DEDICATION

I would like to dedicate this thesis to my beautiful wife Valerie, and our two children, Landon, and Callie. You've inspired me to do my best, and have been the driving force in my completing this journey. Making you proud has made every moment along the way worthwhile. To my parents, thank you for your never-ending support. Your passion and understanding of the swine industry have been integral in my education, and subsequent career decisions.

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CHAPTER 1. GENERAL INTRODUCTION

The purebred swine industry has long been the cornerstone and foundation of pork production in the United States. For many years purebred animals served as the parent lines in commercial operations with a true F1 market hog being the end product, if not the purebred animal itself. Commercial and company lines were originally derived from these purebred populations, and these populations were subsequently revisited when improvements were needed. The evolution of the commercial industry toward composite animals has had a direct negative impact on the viability of the purebred producer. Though in many cases, purebred breeds such as the Duroc and Hampshire are still utilized today as terminal sires, the days of purebred females from breeds such as the Yorkshires and Landrace being used on a major scale have long since passed. The shift in the commercial paradigm was largely, if not solely, due to changes at the packer level in marketing systems. Traditional purebred swine production focused on medium to small independent producers up until the late 1980's. The marketing system incorporated by packers prior to 1985 bought 90 percent of hogs on a live weight basis (Hayenga, 1985). At that point in time, only a small portion of hogs were sold according to their carcass value, and some producers felt the need for change. Subsequent research at the time showed carcass weight, backfat thickness, and muscling index accounted for 79% of the variation in carcass value (Lawrence et al, 2001). The resulting shift led to those factors, largely leanness, being incorporated into a standardized buying matrix providing larger incentives for better carcasses (Hayenga, 1985). Incentive-based systems based on carcass cutability and value quickly became the predominant form of marketing pork. From 1988 to 1997, the percentage of hogs marketed on a carcass basis rose 50 percent (Brorsen et al., 1998). Following the addition of matrix marketing, the U.S. pork industry consolidated rapidly as producers focused on making

an efficient animal both on the farm and at the packing house, and turned more to three-way cross and composite animals to maximize genetic potential and heterosis. In addition, marketing contracts became significantly more lucrative to bigger producers who could supply large numbers on a routine basis, because this allowed the packers more consistent pig flow as well as increased predictability of their end product. Larger commercial producers demanded bigger groups of replacement gilts, which smaller purebred producers were unable to supply.

Additionally, smaller producers were more subject to selling on a live weight basis and at the mercy of demand. In the decade from 1988 to 1997, operations marketing 50,000 hogs or more increased their share of U.S. production from 7 to 37 percent. The share of operations marketing less than 1,000 head annually fell from 32 percent to 5 percent (Lawrence et al., 1998). This caused an immediate and dramatic reduction in purebred populations throughout the nation as genetics were “cherry picked” by commercial companies from the best and largest purebred firms. The culmination of the previously mentioned factors led to purebred swine registries reporting a 45% decline in registrations from 1990 to 2001 (USDA., 2003).

Long term selection criteria for increased lean growth have not come without consequence. Meat and eating quality have declined, and consumer concern has led to the development of niche markets and an overall demand for pork with a greater degree of consumer acceptance. This has developed a new point of focus for the industry and purebred breeders alike. Many breeds have been shown to exhibit meat quality sufficiently superior to mainstream commodity pork to warrant increased demand for their product. Purebred breeders once again hold the key to supplying consumer demand, and possibly an opportunity for a return to relevance that can lead to long term viability. In order to take advantage of the opportunity at hand, research to identify where breeds rank relative to each other for numerous meat quality

traits is needed. The National Barrow Show Sire Progeny Test has served as the premier multi-breed trial for these purposes since 1991. Growth performance and carcass composition are evaluated as well as measurement of meat quality traits. This has allowed purebred producers to make significant strides in producing the best possible product from the farm to the consumer's plate.

The objective of this study was to identify and rank the breeds in the National Barrow Show Sire Progeny Test for growth performance and carcass composition, and to develop growth and tissue deposition curves. The evaluation of intramuscular fat percentage and deposition rate will allow for live animal estimation of this trait, which has been shown to have a favorable correlation to other meat and eating quality measures.

Thesis Organization

This thesis is presented as a general introduction, a literature review, an individual paper, and a general summary. References cited in the general introduction and literature review are reported after the general summary section. All references are cited in compliance with the CBE Style Manual used by the Journal of Animal Science where this paper will be submitted. The paper consists of an introduction, materials and methods, and results and discussion.

CHAPTER 2. LITERATURE REVIEW

Breed Differences in Growth Performance, Carcass Composition, and Meat Quality Traits

The U.S. swine industry was built upon a network of independent swine operations comprised of a number of purebred breeds and combinations of those breeds. Relative differences between breeds are required to develop the best crossbreeding program for maximum profitability. This section will discuss research exploring those differences in growth performance, carcass composition, and meat quality traits. Very few large trials have been conducted where 4 or more breeds have been analyzed for the aforementioned traits.

Goodwin (2004) reported some of the most significant and comprehensive breed analysis to date. Data reported by the National Barrow Show Sire Progeny Test from 1991 through 2004 were analyzed. This report was comprised of 15 test groups containing 6,024 pigs, representing 259 breeders from 22 states. Mixed linear models were applied to the data with fixed effects of breed, sex, and contemporary group. Growth performance evaluation showed Duroc, Landrace, Poland China, and Yorkshire breeds to excel in ADG, but they were not significantly different from each other. Breed evaluation for carcass yield showed an advantage for Chester White, Spot and Yorkshire pigs, while Landrace were significantly better for carcass length than all other breeds. Loin muscle area comparison yielded a significant advantage for the Hampshire breed, and the same advantage was shown for backfat measurements. The Berkshire breed was shown to have less loin muscle area and more backfat than other breeds. Meat quality traits tested revealed a distinct advantage for the Berkshire and Duroc breeds. Durocs had the highest intramuscular fat percentage while Berkshires were among the best for pH, Minolta, and Hunter scores. Berkshires also excelled in drip loss, juiciness, Instron tenderness, and subjective tenderness scores.

The Terminal Sire Line Evaluation Program conducted by the National Pork Producers Council provides extensive comparisons of growth performance, carcass composition, and meat quality traits for different breeds and genetic lines (NPPC, 1995). Genetics used as the terminal component for different marketing schemes were analyzed. Durocs were significantly better for average daily gain when compared to the Berkshire, Yorkshire, Hampshire, and Spot breeds. Hampshires excelled the other breeds for lean gain on test, though they were not significantly different from Durocs. Backfat measures showed Yorkshires and Hampshires were leaner at the tenth-rib than other breeds, while Hampshires had the largest loin muscle area. Spot and Hampshire breeds had the lowest Minolta and ultimate pH scores, while the Berkshire and Duroc breeds excelled in those traits as well as drip loss. Durocs exhibited the highest intramuscular fat percentage. Eating quality traits evaluated were cooking loss percentage, Instron tenderness, tenderness score, and moisture content. Berkshire-sired pigs produced the lowest cooking loss percentage, but were not significantly different from Durocs or Spots. Hampshires were significantly poorer than all other breeds. Berkshires had the best Instron tenderness scores, and Durocs and Spots were not significantly different from each other, but Yorkshires and Hampshires were significantly poorer than all other breeds. Berkshires received the highest tenderness scores but were not significantly different from Durocs or Hampshires. Sensory panel results showed no significant difference among breeds for juiciness, flavor, and off-flavor scores. Final results showed the Hampshire breed to be very useful for producing progeny that will excel in leanness and muscle and more suited to a lean-based matrix. Durocs are versatile based upon the results and will perform well a variety of situations, being the most consistent performer in carcass composition and meat quality traits. Berkshires look to be very successful in meat quality traits and should have the most success in quality based marketing programs.

Young et al. (1976) evaluated growth performance and carcass composition of purebred-sired and crossbred-sired pigs. Feedlot records of 2,111 purebred and crossbred pigs representing all purebred and all possible two-way crosses of the Duroc, Hampshire and Yorkshire breeds were independently analyzed to evaluate average daily gain on test, age at 100 kg, average backfat probe of gilts, average daily feed consumption, and feed conversion. Purebred lines tested were Hampshire, Duroc, and Yorkshire. Durocs were shown to grow significantly faster than the Hampshire or Yorkshire breeds. Hampshires and Yorkshires were leaner than Durocs. Hampshires were also shown to have more loin muscle area and a higher percent lean than Durocs or Yorkshires. Visual marbling scores, firmness, and color all showed significant advantages for the Duroc breed. Hampshires had the poorest color and firmness scores. These results lend credibility to the use of Duroc sires to contribute growth and meat quality of terminal market animals. Hampshires and Yorkshires, to some extent, are best utilized in marketing systems rewarding leanness.

Lo et al. (1992a) studied breed effects on carcass and pork quality traits using a crossbreeding system involving Landrace and Duroc pigs to estimate individual heterosis, direct breed effects and reciprocal cross differences for post-weaning growth, real-time ultrasound, carcass, and pork quality traits. Data from 5,649 pigs and 960 carcasses representing 65 and 49 sires, respectively, were analyzed. Duroc-sired pigs had shorter carcasses, less backfat, more loin muscle area, higher yields, and grew faster than Landrace-sired pigs. Meat quality evaluation showed Durocs also had more intramuscular fat than did Landrace-sired pigs.

Johnson et al. (1973) studied feedlot performance of 941 barrows and gilts and carcass traits of 190 barrows of purebreds and crossbreds of the Duroc, Hampshire and Yorkshire breeds. Differences between purebreds and reciprocal crosses were tested. Purebred and crossbred litters

were farrowed at the Ft. Reno Experiment Station in the 1971 spring and fall farrowing seasons. Significant differences between the pure breeds were evident for most traits. Durocs gained weight faster than Hampshires and Yorkshires, while Yorkshires were the most efficient pure breed. Hampshire barrows had less backfat, more loin eye area, and more total yield of lean cuts than Duroc or Yorkshire barrows. Duroc barrows were superior to the other breeds for quality scores of marbling, firmness and color.

McLaren et al. (1987) evaluated purebred and crossbred performance of the Duroc, Yorkshire, Landrace, and Spotted breeds using data collected at the Oklahoma Agricultural Experiment Station between 1976 and 1979. Individual post-weaning average daily gain, age at 100 kg, and probed backfat thickness at 100 kg data were collected on 3,456 pigs. Duroc-sired pigs grew more efficiently than other sire groups (3.11 vs. 3.21 F/G), and had less BF than other three-breed cross pigs based upon within breed of dam comparisons, suggesting differences in composition between the more efficient Duroc-sired pigs and other breed groups. Landrace-sired pigs were fatter than other sire groups. No real differences between crossbred-sired pigs and the average of contemporary purebred-sired pigs were apparent for F/G, ADF, ADG, AGE or BF.

Baas et al. (1992) used 12 different mating types among the Hampshire and Landrace breeds to determine direct, maternal, heterosis, and recombination effects for performance and carcass traits. Carcass data were collected on 238 barrows and 262 gilts over four replications. Traits measured were length, 10th rib off midline backfat, loin muscle area, and dressing percentage. Average backfat was calculated as the mean of three midline fat depths measured opposite the first rib, last rib, and last lumbar vertebra. Comparisons of reciprocal F1 crosses showed that carcasses from pigs sired by Hampshire boars were leaner and had more LMA than those sired by Landrace boars. For carcass length, comparisons showed that pigs from Landrace

sires or dams were longer than those from Hampshire sires and dams. Purebred Landrace pigs had higher carcass yield than purebred Hampshire pigs. Comparison of breed of dam revealed that pigs from Hampshire dams had 1.8 mm more average backfat and 2.7 mm more 10th rib backfat than did pigs from Landrace dams. Sex effects indicated that gilts had longer and leaner carcasses, more LMA, and a greater dressing percentage.

Newcom et al. (2004) tested myoglobin concentration in the loin muscle to determine breed and gender differences for myoglobin content, to estimate genetic parameters for myoglobin concentration, and to determine the relationship between myoglobin content and objective measures of muscle color. Data from purebred Yorkshire, Duroc, Hampshire, Chester White, Berkshire, Poland China, and Landrace barrows and gilts (n = 255) from the 1999 National Barrow Show Sire Progeny Test were used. Significant breed differences for longissimus myoglobin content were reported, with the Hampshire and Chester White breeds having higher values ($P < 0.05$) than Berkshire, Landrace, Poland China, and Yorkshires. Durocs reported higher values when compared with the Landrace and Yorkshire breeds. Objective color measures showed that Landrace pigs had higher ($P < 0.05$) values (paler color) compared with the Berkshire, Chester White, Duroc, and Hampshire breeds. Breed differences ($P < 0.05$) for Hunter L value measured 24 (L24) and 48 (L48) h postmortem were reported with Landrace and Yorkshire having higher L24 (paler) values compared with the other five breeds in this study. Berkshire pigs had lower L24 values when compared with Chester White, Duroc, Landrace, Yorkshire, and Poland China pigs. Berkshires had the lowest L48 values compared with all other breeds. Chester White and Duroc breeds had lower L48 values when compared with the Yorkshires. Hampshires had the lowest pH value and highest water holding capacity (WHC) value, but were not significantly different from Landrace, Poland China, or Yorkshire pigs for

pH, and were only significantly different from Berkshires and Chester White pigs for WHC . Duroc and Chester White pigs had the most intramuscular fat percentage (IMF). Landrace and Yorkshire pigs had the lowest levels of IMF, but were not different from Hampshires or Poland Chinas.

Gender Differences

Gender plays a significant role in the marketing strategy of most producers due to known differences in growth performance and carcass composition. Potential differences in meat quality traits must be explored as well for niche marketing situations in order for producers to properly manage gender differences in their marketing program to maximize profitability. The following section will give an overview of previous research conducted on these differences with a focus on purebred populations.

Early research was done by Bruner et al. (1968) to compare the effects of sex, season and breed on live and carcass traits. Data were available on 2,508 pigs including the Fall 1954 to Fall 1966 seasons. The Yorkshire, Duroc, Poland China, Landrace, Hampshire, and Spot breeds were compared in the trial. Barrows were shown to have a significantly better average daily gain than gilts, but gilts excelled in feed efficiency. Barrows were shown to exhibit more backfat than gilts, whereas gilts measured more loin muscle area and a higher percent lean on a carcass basis. Similar differences between barrows and gilts were also observed by Herbert and Crown (1956) and Zobrisky et al. (1961).

Skelly et al. (1971) conducted a comprehensive trial researching pork acceptability as influenced by breed, sex, carcass measurements, and cutability. Data were collected on 263 head of barrows and gilts representing the Hampshire, Berkshire, Duroc, and Poland China breeds

over a 4-year period. No significant gender differences were found for average daily gain or carcass yield percentage, even though barrows posted a better gain and gilts were higher for yield. Gilts were significantly leaner and had significantly more loin muscle area. Meat quality evaluation showed no significant differences between barrows and gilts. However, it is important to note data showed barrows measured higher numerically for marbling score while gilts were numerically higher for color, tenderness, and flavor.

Goodwin (2004) is one of the most applicable multi-breed trials completed to date and reports on gender differences as well as previously discussed breed differences. Data reported by the National Barrow Show Sire Progeny Test from 1991 through 2004 were analyzed. This report was comprised of 15 test groups from 6,024 pigs, representing 259 breeders from 22 states. Gender comparison showed barrows to have a significant advantage in growth performance and intramuscular fat percentage relative to gilts. Meat quality comparison showed barrows had a higher pH value, better Instron tenderness scores, and sensory panel evaluation scored barrows higher for juiciness. Gilts were shown to exhibit more loin muscle area and less backfat than barrows. Gilts had better color scores in meat quality evaluation.

The Terminal Sire Line Evaluation Program conducted by the National Pork Producers Council provides extensive gender comparisons of growth performance, carcass composition, and meat quality traits (NPPC, 1995). Data from 3,261 pigs were collected, with 10 different breeds and genetic lines represented. Barrows showed a significant advantage in growth performance; requiring fewer days to reach 113 kg and having higher average daily gain. Gilts had more loin muscle area and less backfat than barrows; however, no significant difference was reported in percent lean. Barrows were shown to have a significant advantage in intramuscular fat percentage, Instron tenderness score, loin lipid content, and sensory panel evaluation of flavor

and tenderness. Gender differences in ultimate pH, drip loss percentage, loin firmness, or color were not significant.

Newcom et al. (2004) tested myoglobin concentration in the loin muscle to determine gender differences for myoglobin content, to estimate genetic parameters for myoglobin concentration, and to determine the relationship between myoglobin content and objective measures of muscle color. Data from purebred Yorkshire, Duroc, Hampshire, Chester White, Berkshire, Poland China, and Landrace barrows and gilts ($n = 255$) from the 1999 National Barrow Show Sire Progeny Test were used. Barrows had an advantage in some color measures. Gilts had lower L48 values than barrows. Barrows had 0.66 greater ($P < 0.05$) percentage of intramuscular fat than gilts. No significant gender differences were observed for other meat quality measures.

Christian et al. (1980) tested 288 crossbred pigs for the effects of sex, breed cross, dietary protein level, and slaughter weight on performance and carcass traits. Barrows grew significantly faster than gilts. Gilts had higher percentages of ham and loin, larger loin eye measurement, and longer carcasses. Barrows were reported to have more backfat ($P < .01$) and higher subjective marbling scores ($P < .05$) than gilts.

Data presented in the aforementioned studies provide consistent representation of gender differences for growth performance, carcass composition, and meat quality traits. Subjective scores aside, data are consistent from trial to trial and provide a strong basis from which gender differences can be deduced.

Genetic Correlations

This section will discuss genetic correlations among growth performance, carcass composition, and meat quality traits. These relationships are crucial in order to understand how selection on a specific trait will positively or negatively impact another trait. Through this understanding, selection indexes can be properly weighted to produce desired improvements in traits of importance without negatively impacting performance in other areas. An understanding of these relationships is critical as steps are taken to improve meat quality in the industry and maintain overall profitability.

Genetic Correlations of Growth Performance and Other Traits

The heritability of growth performance is well documented. This section will briefly discuss genetic correlations for growth performance and ultrasonically measured traits taken in this trial, with a focus on purebred data.

Berger et al. (1994) compiled data from the National Barrow Show Sire Progeny Test representing eight breeds of swine from 135 purebred producers from 20 different states. Data analyzed were from 234 sire groups encompassing the trials from 1991 to 1993. High heritability ($h^2 = 0.58$) was found for growth performance, with a very low antagonistic effect on tenth-rib backfat (-0.038).

Chen et al. (2002) studied genetic parameters and trends for lean growth rate and its components in U.S. Yorkshire, Duroc, Hampshire, and Landrace pigs. Records on 361,300 Yorkshire, 154,833 Duroc, 99,311 Hampshire, and 71,097 Landrace pigs collected between 1985 and April of 2000 in herds on the National Swine Registry Swine Testing and Genetic Evaluation System were analyzed. Animal model and REML procedures were used to estimate random effects of animal genetic, common litter, and maternal genetic, and the covariances between

animal and maternal for lean growth rate (LGR), days to 113.5 kg (DAYS), backfat adjusted to 113.5 kg (BF), and loin eye area adjusted to 113.5 kg (LEA). Estimates of heritabilities were 0.44, 0.44, 0.46, and 0.39 for LGR; 0.35, 0.40, 0.44, and 0.40 for DAYS; 0.48, 0.48, 0.49, and 0.48 for BF; and 0.33, 0.32, 0.35, and 0.31 for LEA in the Yorkshire, Duroc, Hampshire, and Landrace breeds, respectively. Average genetic correlations over 4 breeds were -0.83, -0.37, 0.44, -0.07, 0.08, and -0.37 for LGR with DAYS, BF, and LEA, DAYS with BF and LEA, and BF with LEA, respectively. Average genetic trends were 2.35 g/yr, -0.40 d/yr, -0.39 mm/yr, and 0.37 cm²/yr for LGR, DAYS, BF, and LEA, respectively. Results indicate that selection based on LGR can improve leanness and growth rate simultaneously and can be a useful biological selection criterion.

Stewart and Schinckel (1989) reviewed 175 published papers that evaluated genetic parameter estimates for carcass traits and published their findings for weighted averages of heritabilities and genetic correlations in Genetics of Swine. Traits evaluated were ultrasonic backfat, carcass backfat, loin muscle area, and lean percentage. Moderate to high heritability was shown for all traits ranging from 0.4-0.6. This review also reported a strong relationship between tenth-rib backfat and lean percentage (-0.87), and a strong positive relationship between lean percentage and loin muscle area (0.65).

Lo et al. (1992b) studied heritabilities and genetics correlations of growth, real-time ultrasound, carcass, and pork quality traits in Duroc and Landrace pigs. Data from a mating system involving Landrace and Duroc pigs were used to estimate heritabilities and genetic correlations among growth (ADG), real-time ultrasonic (US) measures of backfat thickness (BF) and longissimus muscle area (LMA), carcass characteristics, and various pork quality traits. Data were collected from 5,649 pigs, 960 carcasses, and 792 loin chops representing 65, 49, and 49

sires, respectively. Heritability estimates were moderate to high for ADG (0.36), USBF (0.54), USLMA (0.46), carcass BF (0.56), and carcass LMA (0.80), percentage of intramuscular fat (0.52), pork tenderness (0.45), and overall acceptability (0.34). Estimates were low to moderate for percentage of cooking loss (0.06), pH (0.14), shear force (0.17), percentage of LM water (0.14), water-holding capacity (WHC) (0.25), pork flavor (0.13), and juiciness (0.12). Genetic correlations between US and carcass measures of BF (0.85) and LMA (0.87) indicate that selection based on US data will result in effective improvement in carcass characteristics. Selection for increased LMA using US is, however, expected to result in decreased IMF (-0.31) and WHC (0.57), increased percentage of LM water (0.48) and shear value (0.41), and in decreased juiciness (-0.31), tenderness (-0.13), and pork flavor (-0.44). Average daily gain was favorably correlated with IMF (0.27) and unfavorably correlated with shear force (-0.27). Selection for increased ADG is expected to improve WHC (-0.55) but to decrease juiciness (-0.50).

Additional research on genetic correlations between growth performance, carcass composition, and ultrasonically measured traits yields a wide range of results. Average daily gain and backfat are shown to range from moderately favorable to moderately unfavorable. Differences in genetics, feeding programs, and measurement methods likely account for a great deal of the variation reported.

Genetic Correlations of Carcass Composition and Meat Quality

The fundamental shift of the swine industry to a lean-based marketing grid in the late 1980's has resulted in a much leaner end product today than ever before (Hayenga, 1985). This shift has resulted in a poorer quality product as a result of an antagonistic effect between lean

gain and meat quality. This section will explore the genetic correlations associated with carcass composition and meat quality measures.

Berger et al. (1994) compiled data from the National Barrow Show Sire Progeny Test representing 8 breeds of swine from 135 purebred producers from 20 different states. Data analyzed were from 234 sire groups encompassing trials from 1991 to 1993. Genetic correlations were analyzed for meat quality traits. Tenth-rib backfat was shown to have a significant genetic correlation with intramuscular fat percentage (0.32), Instron tenderness (-0.25), cooking loss percentage (0.38), cooked moisture percentage (-0.48), and sensory panel evaluation for juiciness (-0.19). Tenth-rib loin muscle area was shown to have a significant genetic correlation with intramuscular fat percentage (-0.37), Instron tenderness (0.18), cooking loss percentage (-0.16), and cooked moisture percentage (0.26). These results illustrate the antagonistic relationship between meat quality traits and increased selection for lean gain.

The Terminal Sire Line Evaluation Program conducted by the National Pork Producers Council provides comparisons of growth performance, carcass composition, and meat quality traits (NPPC, 1995). Data from 3,261 pigs were collected, with 10 different breeds and genetic lines represented. Heritability estimates for ten-rib backfat and loin muscle area were 0.46 and 0.48, respectively. Heritability estimates were 0.25 for Minolta color, 0.38 for ultimate pH, 0.47 for intramuscular fat percentage, 0.08 for cooking loss, and 0.20 for Instron tenderness. Tenth-rib backfat was shown to have a moderate genetic correlation with intramuscular fat percentage (0.30), and with tenth-rib loin muscle area (-0.25). Tenth-rib backfat and loin muscle area showed genetic correlations of (-0.17) and (0.15), respectively, with Instron tenderness scores. All other genetic correlations were not significant. These results are similar to the reported

values by Berger et al. (1994) and lend credibility to the antagonistic nature of lean gain and meat quality.

It is apparent there is a negative correlation between selection for lean gain and meat quality. Meat quality traits tend to be positively correlated to each other which is promising. Selection for intramuscular fat percentage should positively impact other factors affecting meat quality simultaneously. Higher heritability estimates for intramuscular fat also make it a feasible selection alternative.

Tissue Deposition Rates and Growth Curves

Marketing strategies are dictated by knowing the genetics of the animal and subsequent production efficiencies. Understanding tissue deposition rates is the best way to evaluate proper market time market strategy. This section will review recent and pertinent data in this area.

Early research conducted by Quijandria and Robison (1971) used data from 387 Duroc and 390 Yorkshire pigs to evaluate body weight and backfat deposition curves. Weights and measurements were taken at 119, 126, 133, 140, 147, and 154 days of age. Significant differences between each breed and test group were found for growth and backfat curves. Curvilinear growth patterns were reported for age and body weight interaction in Yorkshire pigs. A linear growth pattern was reported for age and body weight interaction Duroc pigs. Curvilinear growth patterns were also reported for age and body weight interaction in boars and gilts, while barrows had a linear growth pattern. Regression of backfat on weight was linear. Final analysis determined the correction factor derived from the pooled data was sufficiently precise to warrant its use across breeds and sexes.

Moeller et al. (1998) recorded serial real-time ultrasonic measurements of backfat and loin muscle area in 648 barrows and 459 gilts representing 8 major U.S. pure breeds of swine.

Real-time ultrasonic measurements of backfat and loin muscle area were collected at average live weights of 67.4, 80.3, 93.4, and 104.9 kg. Significant breed effects were noted for weight gain and for deposition rates of tenth-rib backfat and loin muscle area. Average growth rate for the trial across breeds was 0.774 kg/d. Gender comparison showed barrows grew faster than gilts (0.796 kg/d vs. 0.748 kg/d). Significant breed differences were found for average daily gain with Duroc pigs growing the fastest at 0.835 kg/d, and Chester White pigs growing the slowest at 0.736 kg/d. Across all breeds, tenth-rib backfat was deposited at a mean of 0.271 ± 0.008 mm/kg, with significant differences in deposition rates among the breeds on test. The Chester White breed deposited tenth-rib backfat the fastest at 0.290 mm/kg. The Hampshire breed deposited tenth-rib backfat the slowest at 0.237 mm/kg, while barrows deposited tenth-rib backfat faster (.088 mm/kg) and exhibited more cumulative backfat at each scan period when compared to gilts. The mean deposition rate for tenth-rib loin muscle area was ($0.304 \text{ cm}^2/\text{kg}$) across all breeds. Significant breed differences in tenth-rib loin muscle area deposition were observed with Hampshire progeny depositing loin muscle the fastest $0.331 \text{ cm}^2/\text{kg}$, while Berkshire pigs deposited loin muscle the slowest of the eight breeds on trial ($0.270 \text{ cm}^2/\text{kg}$). Significant breed effects reported in this trial show the importance of understanding growth and tissue deposition patterns of the genetics involved in producing pork relative to the marketing scheme utilized.

Schwab et al. (2007) completed a study evaluating differences in performance, carcass composition, and tissue deposition rates between purebred Duroc lines from two different time periods. Boars from the mid-1980s and boars available in 2006 were used for the trial. This is the first major publication utilizing ultrasound technology to serially scan pigs for estimation of intramuscular fat percentage. Pigs were weighed on test at 63.5 kg and off test at 109 kg. At two-week intervals boars, gilts, and barrows in each line were weighed and ultrasonically evaluated

for tenth-rib loin muscle area, tenth-rib backfat and intramuscular fat percentage. For estimation of intramuscular fat percentage, 4 longitudinal images were collected 7 cm off-midline across the 10th- to 13th-ribs. Final image parameters were generated using texture analysis software and were included in a regression equation developed by Newcom et al. (2002a) to estimate intramuscular fat. A random regression model was fit to the serial data using SAS to model covariances between repeated records, and then fixed and random curves were added to the model to evaluate deposition rates. No significant difference was observed between lines of Duroc pigs from different time periods for average daily gain. Tenth-rib backfat deposition rates showed a significant difference between lines, and a significant difference between boars, barrows, and gilts was also reported. Barrows deposited backfat faster than boars, and gilts had the slowest deposition rate. No difference was detected between lines for loin muscle deposition, the only significant difference reported for loin muscle deposition rate was between barrows from the two different time periods. Analysis of intramuscular fat deposition rate found a significant difference between time periods, with older time period animals depositing intramuscular fat at a faster rate.

Research discussed above indicates a need and understanding of carcass composition and deposition rates for different economically important traits, as well as highlighting the effect of long-term selection for lean gain on intramuscular fat percentage and other meat quality traits. Additionally, it illustrates the usefulness of ultrasound technology in acquiring this information in order to move forward with improvement in production efficiencies and meat quality.

Relationship between Intramuscular Fat and Meat Quality

The genetic advancement of swine toward an efficient animal with an emphasis on lean gain has led the industry to a crossroads between meat quality/consumer acceptance and

economic gain as dictated by the packer. Research indicating intramuscular fat as a predictor of overall meat quality is well documented. This section will briefly discuss the general relationship between meat quality and intramuscular fat, and what has led to its use as the only meat quality indicator in live animals.

Researchers have investigated a multitude of traits to evaluate the concept of meat quality (NPPC, 1995). Many varying methods have been used to measure intramuscular fat, from chemical evaluation to subjective marbling scores. Nevertheless, in general, research has shown intramuscular fat percentage to be a key indicator of meat quality, especially in the live animal, and to impact a number of other measures crucial to meat quality and consumer acceptance.

A comprehensive research review was done by Sellier (1998), reviewing 175 scientific papers involving meat quality genetic parameters. The most significant finding was a relatively high heritability for intramuscular fat percentage (0.50), the highest of all meat quality traits, and its corresponding correlation (0.61) to sensory panel scores for eating quality.

Newcom et al. (2002b) confirmed the relationship between intramuscular fat percentage and sensory panel scores that Sellier (1998) reported in the review discussed above. Results showed an average intramuscular fat percentage heritability of 0.48. Chemical intramuscular fat was shown to have a very favorable correlation to sensory panel traits. Genetic correlations for juiciness, tenderness, chewiness, flavor, and off-flavor traits with intramuscular fat were 0.18, 0.36, 0.43, 0.16, and 0.16, respectively.

Huff-Lonergan et al. (2002) studied correlations among selected pork quality traits. A 3-generation resource family was developed from 2 Berkshire sires and 9 Yorkshire dams, a total of 525 F2 animals were used in the study. Pigs were slaughtered at approximately 110 kg, at which time carcass composition traits, pH measurements, and subjective quality scores were

made at 24 h postmortem. Loin samples (n = 525) were collected at 48 h postmortem and meat quality traits were evaluated. Marbling score was shown to have a moderate to low positive correlation to firmness (0.37), drip loss (-0.12), cooking loss (-0.11), and tenderness (0.21). Marbling was also positively correlated with flavor scores and negatively correlated with off-flavor scores. Similar positive correlations were found when comparing percent intramuscular lipid and sensory panel evaluation.

Murray et al. (2004) reported elevated levels of intramuscular fat to be positively correlated with higher juiciness, flavor, tenderness, and overall palatability scores. Most importantly, however, may be the significant correlation reported between percent intramuscular lipid and 24 h pH (0.57).

Lonergan et al. (2007) studied the influence of lipid content on pork sensory quality within pH classification. Data were analyzed on 1,535 pigs from 248 sires and 836 dams from the 1991, 1992, and 1994 National Barrow Show Sire Progeny Tests. Purebred Berkshire (107), Chester White (113), Duroc (249), Hampshire (220), Landrace (165), Poland China (101), Spotted (181), and Yorkshire (399) pigs were evaluated. A total of 901 barrows and 634 gilts were used for the trial. A pH classification of LM was assigned as follows: class A, >5.95 , n = 186; class B, ≥ 5.80 to 5.95, n = 236; class C, ≥ 5.65 to 5.80, n = 467; class D, ≥ 5.50 to 5.65, n = 441; class E, <5.50 , n = 205. Lipid content was a significant source of variation for models predicting star probe values in class C and D and for chewiness in class B, C, and D. Increasing lipid content tended to increase sensory tenderness in pH class D. Lipid content was not a significant source of variation for juiciness scores within any pH class. The highest correlation with sensory texture traits occurred in classes C and D. Within class C and D, correlations

indicate that increasing lipid content is associated with high sensory tenderness, low sensory chewiness, and low star probe values.

In the development of improvement strategies for pork quality, a comprehensive understanding of the animal is required. Traits such as backfat, loin muscle area, and intramuscular fat percentage have been and will continue to be of paramount importance. Implementation of ultrasound technology for accurate prediction of traits allows for selection within breeding stock populations. Selection at this level is required to rectify deficiencies in pork quality as quickly as possible. The knowledge and technology are in place to make significant pork quality improvements. The final step is to apply that knowledge and utilize the resources at our disposal in genetic selection.

**Chapter 3. COMPARISON OF CARCASS COMPOSITION, PERFORMANCE, AND
TISSUE DEPOSITION RATES AMONG BREEDS OF SWINE**

A paper to be submitted to the *Journal of Animal Science*

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Abstract: A study was conducted to evaluate differences in performance, carcass traits, and tissue deposition rates among different breeds of swine entered in the 2003 National Barrow Show Progeny Test. The test consisted of 362 animals representing 8 different breeds. Breeds tested were Berkshire (n = 158), Duroc (n = 76), Chester White (n = 53), Yorkshire (n = 31), Spotted Poland China (n = 15), Landrace (n = 15), Poland China (n = 8), and Hampshire (n = 6). Due to small sample size, the Spotted Poland China, Landrace, Poland China, and Hampshire breeds were combined in an All Other Breeds (AOB) category. The trial consisted of barrow and gilt progeny from sires in each breed. Progeny were weighed and scanned beginning at a group mean body weight (BW) of approximately 64 kg. Deposition rates were estimated for 10th rib loin muscle area (LMA), 10th rib off-midline backfat (BF10), and intramuscular fat percentage (IMF) of the longissimus dorsi by serially scanning all pigs every 2 weeks until they reached a mean off test weight of approximately 109 kg. Yorkshires and Durocs grew faster ($P < 0.05$) than Berkshires and Chester Whites. Yorkshires, Durocs, and AOBs had less ($P < 0.05$) BF10 than Chester Whites and Berkshires. Chester Whites had less ($P < 0.05$) BF10 than Berkshires. Durocs had more LMA ($P < 0.05$) than any other breed. Durocs, Yorkshires, Chester Whites, and AOB had significantly more LMA than Berkshires. Durocs had more IMF ($P < 0.05$) than any other breed, and Chester Whites had more IMF ($P < 0.05$) than Yorkshires, AOB, and Berkshires. Serial measurement of backfat deposition showed a linear pattern of deposition from 64 to 109 kg. Durocs and Yorkshires deposited backfat at a lower rate ($P < 0.05$) than all other breeds. Berkshires deposited backfat at a greater rate ($P < 0.05$) than all other breeds. Cumulative deposition rates for LMA and IMF were linear, while BF10 deposition was curvilinear. This study illustrates significant breed differences in growth performance and IMF, BF10, and LMA

deposition rates. Results show commercial applicability for breeds such as Durocs and Yorkshires, while illustrating niche market potential for breeds such as Berkshire.

Key Words: Swine, Breed, Deposition Rates

Introduction

The purebred swine industry has historically been the foundation for the commercial swine industry. Commercial companies began with subsets of animals from these gene pools, and still sample and add different breeds/genetics today. Market conditions, productivity differences, input costs, and a more discerning consumer all drive the pork industry toward improvement and evolution. No one genetic line will likely satisfy the complex world pork market, thus genetically diverse populations of pigs remains crucial. Purebred swine associations and their breeders have never been more important. The National Barrow Show Sire Progeny Test is a unique test that annually compares economically important traits from different breeds of swine, irregardless of their importance to niche markets or traditional buying grids. This test allows comparisons both within and among breeds, as well as between sexes. Genetics from different farms across the United States are represented. Utilization of lean incentive based marketing (Borsen et al., 1998) by packers and continued development of niche markets makes an understanding of breed differences more important today than ever before. The United States swine industry is truly feeding the world in a global market. Diverse cultures require different pork products and utilization of the animal, and these demands have led to additional research and trait exploration by researchers.

Live weight was the single determining factor in market hog pricing prior to 1985 (Hayenga et al., 1985). As demand grew for a leaner product, the market evolved to include

carcass based pricing that is predominate today. In recent years, increased demand for products possessing higher meat quality has resulted in scientific research focused on meat quality traits. Consumer demand may drive the evolution of the market to a point where a quality factor will change from a niche market basis to being included in standard marketing grids. As a result, traits such as intramuscular fat percentage, pH, and water holding capacity have become more important. One of the few trials where standardized comparisons can be made is the National Barrow Show Sire Progeny Test. The objective of this study was to evaluate differences in performance, carcass traits, and tissue deposition rates among different breeds of swine entered in the 2003 National Barrow Show Sire Progeny Test.

Materials and Methods

The 2003 National Barrow Show Progeny Test consisted of 362 pigs representing eight breeds of swine. Pigs from Berkshire (n = 158), Duroc (n = 76), Chester White (n = 53), Yorkshire (n= 31), Spotted Poland China (n = 15), Landrace (n = 15), Poland China (n = 8), and Hampshire (n = 6) breeds were evaluated. Due to small sample size the Spotted Poland China, Landrace, Poland China, and Hampshire breeds were combined in an All Other Breeds (AOB) category. Pigs were housed in a totally enclosed facility with mechanical ventilation and totally slatted floors. Pigs were allotted 1.86 m² per pig and tested in sire groups of 8 head from approximately 64 kg to 109 kg. of BW.

The number of pigs evaluated from each breed, as well as gender distribution, is shown in Table 1. Beginning at a sire group mean weight of approximately 64 kg, barrows and gilts from each pen were weighed, and ultrasonically measured for tenth-rib backfat (BF10), tenth-rib loin muscle area (LMA), and intramuscular fat percentage (IMF) every two weeks. Pigs were

weighed off-test at an approximate mean live weight of 109 kg., at which time a final ultrasonic measure of BF10, LMA, and IMF were collected. Ultrasound images were collected using an Aloka 500V SSD ultrasound machine with a 3.5 MHz, 12.5 cm linear-array transducer (Corometrics Medical Systems Inc., Wallingford, CT), and all scanning was performed by a National Swine Improvement Federation certified technician. A custom designed standoff pad was used to fit the transducer to the natural curve of the animal's back, and vegetable oil was applied as conducting material between the probe and skin. Two cross-sectional images of the animal's longissimus dorsi were captured at the 10th rib location to estimate off-midline backfat (BF10) and loin muscle area (LMA). Four longitudinal images were obtained to predict intramuscular fat (IMF) across the 10th – 13th ribs, with the transducer positioned 7 cm off mid-line and the stand-off pad removed. A regression equation developed by Newcom et al. (2002) and texture analysis software (Amin et al, 1997), were used to estimate IMF.

Statistical Analysis

The evaluation of breed and sex differences for growth performance, carcass composition, and tissue deposition rates were accomplished using statistical analysis software (SAS Inst. Inc., Cary, NC).

Performance traits. Growth performance and traits evaluated at the completion of the trial were analyzed using a linear mixed model (PROC MIXED) using Statistical Analysis System (SAS) software (SAS Inst. Inc., Cary, NC):

$$y_{ijklmnp} = B_i + S_j + SG_k + RN_l + OTW_m + PS_n + PD_p + E_{ijklmnp}$$

where

$y_{ijklmnp}$ = trait measured on the mth pig of the ith breed of the jth sex in the kth scan group in the lth room;

B_i = fixed effect of the i^{th} breed (1-5);

S_j = fixed effect of the j^{th} sex (1-2);

SG_k = fixed effect of the k^{th} scan group determined by initial scan date (1-10);

RN_l = fixed effect of the l^{th} room in test barn (1-4);

OTW_m = linear effect of off-test weight of the m^{th} pig;

PS_n = effect of the n^{th} sire, assumed random with $PS(B)_{ni} \sim N(0, \sigma_{PS}^2)$;

PD_p = effect of the p^{th} dam, assumed random with $PD_p \sim N(0, \sigma_{PD}^2)$; and

$E_{ijklmnp}$ = residual with $E_{ijklmnp} \sim N(0, \sigma_E^2)$, assumed random.

Model development was the result of fitting all two-way interactions between fixed effects as well as second order polynomial effects of the covariate OTW and sequentially removing all non-significant effects.

Serially measured traits. Traits measured serially included BF10, LMA, IMF, and body weight (BW). A random regression model was implemented using SAS (SAS Inst. Inc., Cary, NC) to model covariances between repeated records of the serially measured traits. To analyze deposition rates of serially measured traits, fixed and random curves were added to the previous model. First and second order polynomial effects of OTW were implemented by breed for the analysis of serially measured BF10, LMA, IMF, and corresponding deposition rates. An unstructured covariance structure was used for repeated records while an autoregressive covariance structure was used for residual effects. Backward elimination was used to remove non-significant fixed effects from the model.

Results and Discussion

Least squares means (\pm SE) for average daily gain and carcass composition from a trial comparing different breeds of swine are presented in Table 2.

Growth Performance

Average daily gain. Yorkshires and Durocs had a greater ADG ($P < 0.05$) than Berkshires and Chester Whites over the entire test period. Similar results were reported by Moeller et al. (1998) for Duroc superiority in a multi-breed trial. Significant differences ($P < 0.05$) were observed between sexes for the duration of the trial with barrows growing faster than gilts. This is consistent with the findings of Stewart and Schinckel (1989) and (NPPC, 1995). In the current study, Duroc barrows grew significantly faster than Berkshire and AOB barrows. Chester White and Berkshire gilts grew significantly slower than Yorkshire, Duroc, and AOB breed gilts.

Ultrasonically Measured Traits

Significant differences for tenth-rib backfat were found among breeds and between barrows and gilts. Yorkshire, Duroc, and AOB breeds had less BF10 ($P < 0.05$) than Chester Whites and Berkshires, and Chester Whites were leaner ($P < 0.05$) than Berkshires. Barrows had more BF10 ($P < 0.05$) within each breed than gilts, a result supported by previous research by Moeller et al. (1998) and Schwab et al. (2007).

Durocs had more ($P < 0.05$) LMA and Berkshires had less ($P < 0.05$) LMA when compared to the other breeds on test. Similar results were reported by Moeller et al. (1998) in a trial comparing 8 breeds of swine. In that trial, Hampshires had the largest LMA, followed by Durocs, and Berkshires had the smallest LMA when compared to the other breeds evaluated. In the current study, Duroc barrows also had the most LMA ($P < 0.05$) when compared to other breeds, while Duroc gilts had significantly more LMA than Chester White, Yorkshire, and

Berkshire gilts. The AOB gilts had more LMA ($P < 0.05$) when compared with Yorkshire and Berkshire gilts, and Berkshire gilts had less LMA ($P < 0.05$) than all breeds evaluated in the present study. Gilts had significantly more LMA than barrows. This is a result supported by the findings of Christian et al. (1980), in a trial that evaluated 288 crossbred pigs for the effects of sex, breed cross, dietary protein level, and slaughter weight on performance and carcass traits. They reported gilts had higher percentages of ham and loin, larger loin eye measurement, and longer carcasses.

Durocs had more IMF than all other breeds on test. This finding is supported by research completed by the National Pork Producers Council in the Terminal Sire Line Evaluation Program (NPPC, 1995). The Duroc breed was shown to have greater IMF when compared to other breeds and company lines. Goodwin (2004) summarized data from the National Barrow Show Progeny Test, analyzing data from 8 breeds from 1991 to 2004 and also concluded Durocs had the most IMF of any breed evaluated. In the current study, Duroc barrows and gilts had more ($P < 0.05$) IMF than the other breeds evaluated. Chester Whites had more IMF ($P < 0.05$) than Yorkshires, Berkshires, and AOB breeds. Yorkshire and Chester White barrows had more IMF ($P < 0.05$) than Berkshire barrows. Chester White gilts scanned more IMF ($P < 0.05$) than Yorkshire, Berkshire, and AOB gilts.

Overall evaluation of off-test data for BF10, LMA, and IMF provides distinct advantages and disadvantages for different breeds evaluated in the current study. Durocs were among the leanest at the tenth rib while simultaneously having the most LMA and IMF in this trial. In contrast, the Berkshire breed proved to be less competitive, having significantly more BF10, less LMA, and ranking low for IMF.

Serially Measured Traits

Mean deposition rates for BF10, LMA, and IMF are listed in Table 3. Cumulative tissue deposition patterns for BF10, LMA, and IMF are presented in Figures 1 to 8 by breed and sex. Deposition rate analysis for BF10 showed Yorkshires and Durocs were superior to Chester Whites, Berkshires, and All Other Breeds, depositing less backfat per kg of BW gain ($P < 0.05$). Chester Whites and All Other Breeds deposited backfat at a slower rate ($P < 0.05$) when compared to Berkshires, a result in contradiction of Moeller et al. (1998) in which Chester White pigs deposited backfat at the fastest rate. Differences between the numbers of pigs represented for each breed, the different sires evaluated, as well as the possibility that Chester Whites have had more genetic improvement in the intermittent time period, are all possible explanations for the difference in the results of the two trials. In the current study, Yorkshire and Duroc barrows deposited backfat at a slower rate ($P < 0.05$) than the other breeds evaluated, and AOB barrows also deposited backfat at a lower rate ($P < 0.05$) when compared to Berkshire and Chester White barrows. Duroc gilts deposited less backfat per kg of BW gain ($P < 0.05$) than Berkshire, Chester White, and AOB gilts, the rate of deposition for Yorkshire gilts was also less ($P < 0.05$) than for Berkshires.

Deposition rates for LMA showed Yorkshires and Durocs deposited more ($P < 0.05$) LMA per kg of BW gain than Berkshires and Chester Whites. Berkshire deposition rates were lower ($P < 0.05$) than all other breeds on test, which agrees with Moeller et al. (1998). Duroc barrows deposited LMA at a faster rate than Chester White, Berkshire, and AOB barrows. Deposition rates for Berkshire barrows were significantly lower than all other breeds on test. Deposition rates for Berkshire gilts were lower ($P < 0.05$) than Yorkshire, Duroc, and AOB gilts.

In this study, Durocs and Chester Whites had significantly higher IMF deposition rates than Yorkshires and AOBs, a result supported by the finding of Goodwin (2004). Both studies reported Yorkshires were the poorest for IMF deposition rate. In the current study, Chester White barrows deposited IMF at a greater rate than AOB and Yorkshire barrows. Deposition rates of IMF for Yorkshire barrows were significantly lower than all other breeds on test. Deposition rate for Duroc gilts were significantly greater than for AOB gilts, but no other significant differences were detected among the other breeds of gilts evaluated in the current study.

As expected, daily deposition rate differences between breeds follow a similar pattern to the cumulative results. The noticeable change in breed differences for traits from the beginning of the trial to its conclusion are explained well by differences in daily tissue deposition rates.

Serial measurements for ADG, BF10, and LMA yielded curvilinear patterns by both breed and sex, while IMF yielded a linear pattern for both breed and sex. Figure 1 shows that most breeds continue to increase growth rate over time. However, pigs in the AOB class reported decreased growth rate per day from 100 kg to the conclusion of the trial. Barrows and gilts show very similar growth patterns with barrows having a higher rate of gain per day.

Figures 3 and 4 show similar BF10 deposition patterns for all breeds, with all breeds increasing BF10 over time as BW increased. A curvilinear BF10 deposition pattern was found in this trial, while others (Hetzer et al., 1956; Noffsinger et al., 1959; and Quijandria and Robinson, 1971) have shown a linear pattern of deposition. Differences in the weight ranges tested may account for the conflicting pattern of deposition when compared to the current study.

Cumulative LMA estimates by breed and sex shown in Figures 5 and 6, respectively, show a curvilinear relationship between BW and LMA tissue deposition for all breeds evaluated

in the current study. This result is supported by findings of Casey (2003), and Schwab et al. (2007).

Figures 7 and 8 show cumulative IMF deposition by breed and sex. A linear pattern of deposition within the weight range evaluated in the present study is shown. A significant advantage was observed for Duroc and Chester White breeds when compared to the other breeds evaluated. Schwab et al. (2007) reported a curvilinear pattern of cumulative IMF deposition in a trial comparing different genetic lines within the Duroc breed. This discrepancy is likely a result of having five breed groups represented in the current study, with only the Duroc breed represented in Schwab et al. (2007). Duroc and Chester White breeds have been reported to excel in IMF in previous research when compared to other breeds or lines (Goodwin, 2004 and Newcom, 2004).

Deposition rates for BF10 per kg of BW gain are plotted by breed and sex in Figures 9 and 10, respectively, and show a curvilinear pattern, a result supported by McLaren et al. (1989). Gu et al. (1992) found BF10 deposition to be linear in a serial slaughter study of 5 different genotypes. This differing result may be due to the method of measurement, i.e. ultrasound vs. in-plant carcass measurement. Smith et al. (1992) reported a curvilinear backfat deposition pattern over a weight range from 20 to 118 kg, which agrees with the present findings in this study. In the current study, the Duroc and AOB pigs BF10 deposition rate increases at an increasing rate over the entire test period, whereas most other breeds are slowing significantly in BF10 deposition rate from 100 to 109 kg.

Deposition rates of LMA per kg of BW gain breed and sex are plotted in Figures 11 and 12, respectively, showing a linear pattern for LMA deposition rate throughout the trial. This result is supported by Schwab et al. (2007). The rate of deposition for Berkshires is significantly

lower than all other breeds, decreasing from the start to the end of the trial. All other breeds showed a linear increase in LMA deposition rate per kg of BW gain throughout the test period.

Deposition rates of longissimus dorsi IMF per kg of BW gain by breed and sex are plotted in Figures 13 and 14, respectively. A linear pattern of IMF deposition rate by breed and sex were found in the current study. This result is supported by Schwab et al. (2007) in a trial comparing IMF deposition patterns for Durocs from two different time periods. The current time period pigs in that trial showed a mean deposition rate of 0.011 ± 0.002 IMF/kg and a linear pattern of deposition. In the current study, Duroc pigs also had a linear pattern of deposition, and a mean deposition rate of 0.010 ± 0.002 IMF/kg. However, Schwab et al. (2007) reported a linear increase in IMF deposition rate per kg of BW gain for Durocs, while in the current study, Durocs decreased in a linear pattern for IMF deposition rate per kg of BW gain throughout the trial. In the current study, Chester White and Yorkshire breeds increase IMF deposition rate per kg of BW gain linearly throughout the trial, while Berkshire and AOB pigs are relatively constant (flat) for the duration of the trial. Additional discussion is warranted in reference to Yorkshire IMF deposition rate, where the value at the beginning on the test is actually negative. This is likely a result of phenotypic traits of the breed, limitations of the software, and small sample size. Yorkshires were the leanest breed in the trial and estimation of IMF is more difficult in leaner animals, particularly at lighter weights.

Results from this trial demonstrate inherent differences in breeds of swine for growth performance, carcass composition, and a measure of meat quality. These differences offer potential for the purebred swine industry to adapt and fit a variety of market demands and consumer preferences. Divergent paths of selection by different breeds have yielded genetic differences with the potential to develop animals that will be competitive in the most stringent

modern marketing matrix or in a niche market situation. This trial was conducted under modern confinement conditions, and thus we cannot discern whether additional advantages and/or disadvantages exist for specific breeds under different conditions. Furthermore, technologies in ultrasound allow estimation of growth curve and tissue deposition rates to permit producers to produce the best end product for their system.

Literature Cited

- Amin, V., D. Wilson, and G. Rouse. 1997. USOFT: An ultrasound image analysis software for beef quality research. A. S. Leaflet R1437. Iowa State University, Ames, IA.
- Brorsen, B. W., J. T. Akridge, M. A. Boland, S. Mauney, and J. C. Forrest. 1998. Performance of alternative component pricing systems for pork. *J. Agric. Appl. Econ.* 302:313–324.
- Casey, D. S. 2003. The use of electronic feeders in genetic improvement programs for swine. Ph.D. Thesis. Iowa State Univ., Ames, IA.
- Christian, L. L., K. L. Strock, and J. P. Carlson. 1980. Effects of protein, breed cross, sex and slaughter weight on swine performance and carcass traits. *J. Anim. Sci.* 51:51-58.
- Goodwin, R. N. 2004. Growth, Carcass and Meat Quality Trait Performance of Pure Breeds. Annual Meeting. Natl. Pork Prod. Council., Des Moines, IA. Available: www.nsis.com/conferences/2004/pdf/RodneyGoodwinPresentation.pdf. Accessed May 15th, 2008.
- Gu, Y., A. P. Schinckel, and T. G. Martin. 1992. Growth, development, and carcass composition in five genotypes of swine. *J. Anim. Sci.* 70:1719–1729.
- Hayenga, M. L., B. S. Grisdale, R. G. Kauffman, H. R. Cross, and L. L. Christian. 1985. A carcass merit pricing system for the pork industry. *Am. J. Agric. Econ.* 67:315–319.
- Hetzer, H. O., J. H. Zeller, and O. G. Hankins. 1956. Carcass yields as related to live hog probes at various weights and locations. *J. Anim. Sci.* 15:257–270.
- McLaren, D. G., F. M. McKeith, and J. Novakofski. 1989. Prediction of carcass characteristics at market weight from serial real-time ultrasound measures of backfat and loin eye area in the growing pig. *J. Anim. Sci.* 67:1657-1667.
- Moeller, S. J., L. L. Christian, and R. N. Goodwin. 1998. Development of adjustment factors for backfat and loin muscle area from serial real-time ultrasonic measurements on purebred lines of swine. *J. Anim. Sci.* 76:2008-2016.
- NPPC. 1995. Genetic Evaluation/Terminal Line Program Results. R. Goodwin and S. Burroughs, ed. Natl. Pork Prod. Council., Des Moines, IA.
- Newcom, D. W., T. J. Baas, and J. F. Lampe. 2002. Prediction of intramuscular fat in live swine using real-time ultrasound. *J. Anim. Sci.* 80:3046–3052.
- Newcom, D. W., K. J. Stalder, T. J. Baas, R. N. Goodwin, F. C. Parrish, and B. R. Wiegand. 2004. Breed differences and genetic parameters of myoglobin concentration in porcine longissimus muscle. *J. Anim. Sci.* 82:2264–2268.

- Noffsinger, T. L., F. N. Andrews, and V. L. Anderson. 1959. The rate of fat deposition in four lines of swine. *J. Anim. Sci.* 18:127–133.
- Quijandria, B., and O. W. Robison. 1971. Body weight and backfat deposition in swine: Curves and correction factors. *J. Anim. Sci.* 33:911–918.
- SAS Institute, Inc. 1999. SAS/STAT[®] User's Guide, Version 8. SAS Institute, Inc., Cary, NC
- Schwab, C. R., T. J. Baas, K. J. Stalder, and J. W. Mabry. 2007. Deposition rates and accretion patterns of intramuscular fat, loin muscle area, and backfat of Duroc pigs sired by boars from two time periods. *J. Anim. Sci.* 85:1540-1546.
- Smith, B. S., W. R. Jones, J. D. Hough, D. L. Huffman, W. B. Mikel, and D. R. Mulvaney. 1992. Prediction of carcass characteristics by real-time ultrasound in barrows and gilts slaughtered at three weights. *J. Anim. Sci.* 70:2304–2308.
- Stewart, T. S., and A. P. Schinckel. 1989. Genetic parameters for swine growth and carcass traits. *Genetics of Swine*. pp.77-79.

Table 1. Distribution of records from a trial comparing different breeds of swine

Trait Category	Number of Animals					
	Total	Yorkshire	Duroc	Chester White	Berkshire	All Other Breeds²
Growth & Ultrasonic Measurement ¹	362	31	76	53	158	44
Gender						
Barrow	199	14	28	32	98	27
Gilt	163	17	48	21	60	17

¹Off-test measurements for average daily gain, tenth-rib backfat, loin muscle area, and intramuscular fat percentage.

²AOB category comprised of Hampshire, Landrace, Poland and Spot breeds.

Table 2. Least squares means (\pm SE) for average daily gain and carcass composition from a trial comparing different breeds of swine

Item	Breed				
	Yorkshire	Duroc	Chester White	Berkshire	All Other Breeds ¹
Growth Performance					
Average daily gain, kg/d	0.87 \pm 0.02 ^a	0.88 \pm 0.01 ^a	0.83 \pm 0.02 ^b	0.83 \pm 0.01 ^b	0.85 \pm 0.02 ^{ab}
Barrow	0.88 \pm 0.03 ^{ab}	0.94 \pm 0.02 ^a	0.90 \pm 0.02 ^{ab}	0.86 \pm 0.01 ^b	0.88 \pm 0.02 ^b
Gilt	0.86 \pm 0.03 ^a	0.81 \pm 0.02 ^a	0.75 \pm 0.02 ^b	0.80 \pm 0.01 ^b	0.82 \pm 0.02 ^a
Ultrasonic Measurement					
Tenth-rib backfat, cm	1.27 \pm 0.06 ^a	1.37 \pm 0.04 ^a	1.65 \pm 0.05 ^b	1.78 \pm 0.03 ^c	1.40 \pm 0.05 ^a
Barrow	1.35 \pm 0.07 ^a	1.43 \pm 0.05 ^a	1.73 \pm 0.05 ^b	1.95 \pm 0.04 ^c	1.47 \pm 0.06 ^a
Gilt	1.19 \pm 0.07 ^a	1.30 \pm 0.05 ^a	1.58 \pm 0.06 ^b	1.62 \pm 0.04 ^c	1.33 \pm 0.06 ^a
Loin Muscle					
Area, cm ²	30.95 \pm 0.58 ^b	34.19 \pm 0.39 ^a	32.22 \pm 0.46 ^b	29.00 \pm 0.33 ^c	32.34 \pm 0.49 ^b
Barrow	30.59 \pm 0.72 ^b	33.64 \pm 0.52 ^a	31.85 \pm 0.52 ^b	28.50 \pm 0.36 ^c	31.10 \pm 0.56 ^b
Gilt	31.31 \pm 0.73 ^c	34.75 \pm 0.45 ^a	32.59 \pm 0.60 ^{bc}	29.53 \pm 0.39 ^d	33.61 \pm 0.63 ^{ab}
Intramuscular fat, %					
	3.08 \pm 0.09 ^c	3.59 \pm 0.06 ^a	3.30 \pm 0.07 ^b	2.96 \pm 0.05 ^c	3.00 \pm 0.08 ^c
Barrow	3.22 \pm 0.12 ^b	3.67 \pm 0.09 ^a	3.37 \pm 0.08 ^b	2.95 \pm 0.06 ^c	3.05 \pm 0.09 ^{bc}
Gilt	2.95 \pm 0.12 ^c	3.51 \pm 0.07 ^a	3.24 \pm 0.10 ^b	2.98 \pm 0.06 ^c	2.94 \pm 0.10 ^c

^{abcd}LS means with different superscripts within a row are different ($P < 0.05$).

¹AOB category comprised of Hampshire, Landrace, Poland and Spot breeds.

Table 3. Least squares means (\pm SE) for deposition rates of tenth-rib backfat, loin muscle area, and percent intramuscular fat averaged over the entire test period from a trial comparing different breeds of swine

Item ¹	Breed				
	Yorkshire	Duroc	Chester White	Berkshire	All Other Breeds ²
BF10, mm/kg					
Overall	0.095 \pm 0.015 ^a	0.103 \pm 0.011 ^a	0.175 \pm 0.012 ^b	0.205 \pm 0.009 ^c	0.151 \pm 0.013 ^b
Barrow	0.098 \pm 0.019 ^a	0.122 \pm 0.016 ^a	0.224 \pm 0.015 ^c	0.245 \pm 0.010 ^c	0.169 \pm 0.015 ^b
Gilt	0.092 \pm 0.020 ^{ab}	0.084 \pm 0.013 ^a	0.127 \pm 0.016 ^b	0.165 \pm 0.011 ^c	0.134 \pm 0.017 ^{bc}
LMA, cm ² /kg					
Overall	0.270 \pm 0.013 ^a	0.280 \pm 0.010 ^a	0.233 \pm 0.011 ^b	0.189 \pm 0.008 ^c	0.254 \pm 0.011 ^{ab}
Barrow	0.273 \pm 0.017 ^{ab}	0.297 \pm 0.014 ^a	0.248 \pm 0.013 ^b	0.180 \pm 0.009 ^c	0.257 \pm 0.013 ^b
Gilt	0.266 \pm 0.017 ^a	0.262 \pm 0.011 ^a	0.218 \pm 0.014 ^{ab}	0.198 \pm 0.09 ^b	0.250 \pm 0.015 ^a
IMF, %/kg					
Overall	-0.002 \pm 0.003 ^c	0.010 \pm 0.002 ^a	0.011 \pm 0.002 ^a	0.006 \pm 0.001 ^{ab}	0.002 \pm 0.002 ^{bc}
Barrow	-0.008 \pm 0.004 ^c	0.009 \pm 0.003 ^{ab}	0.016 \pm 0.003 ^a	0.009 \pm 0.002 ^{ab}	0.003 \pm 0.003 ^b
Gilt	0.005 \pm 0.004 ^{ab}	0.011 \pm 0.003 ^a	0.005 \pm 0.003 ^{ab}	0.003 \pm 0.002 ^{ab}	0.002 \pm 0.003 ^b

^{abc}LS means with different superscripts within a row are different ($P < 0.05$).

¹BF10 = Tenth-rib backfat; LMA = Tenth-rib Loin muscle area; IMF = Intramuscular fat percentage

²AOB category comprised of Hampshire, Landrace, Poland and Spot breeds.

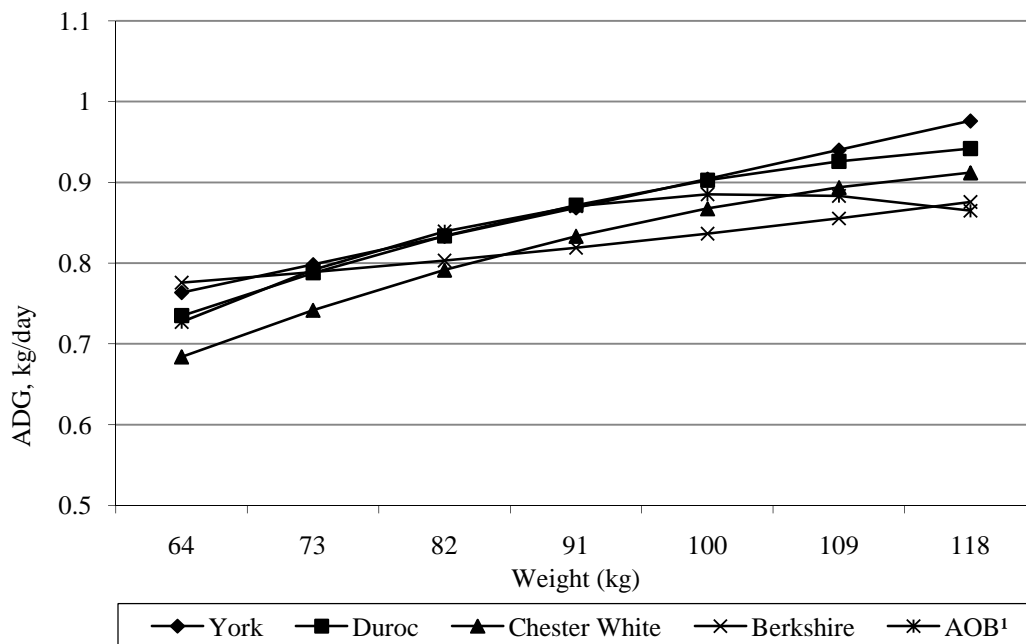


Figure 1. Average daily weight gain from a trial comparing different breeds of swine.
¹AOB category comprised of Hampshire, Landrace, Poland and Spot breeds.

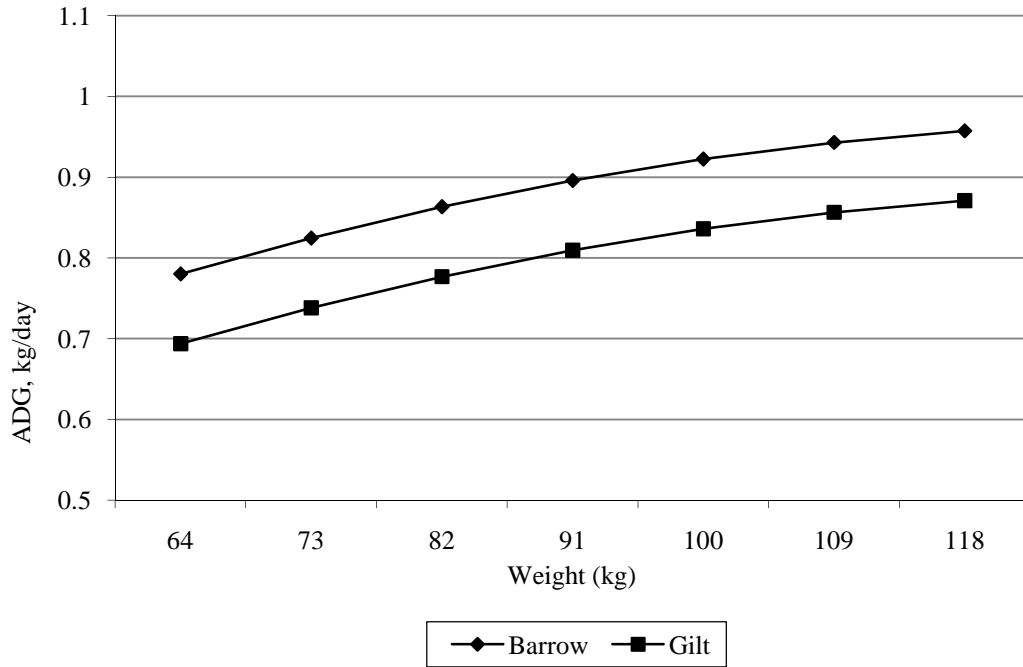


Figure 2. Average daily weight gain by sex from a trial comparing different breeds of swine.

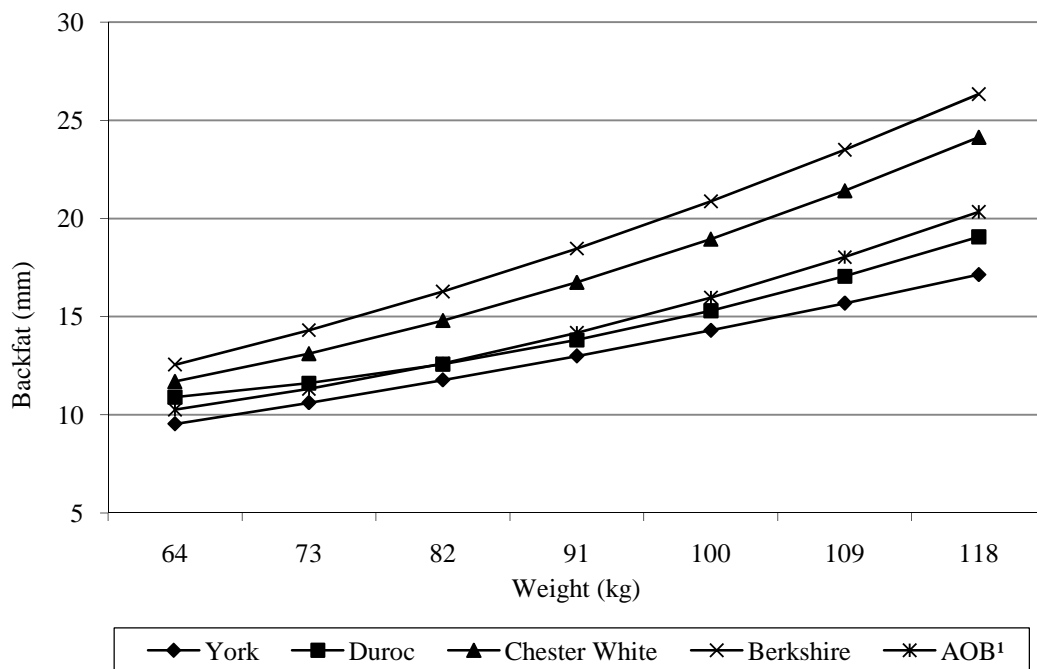


Figure 3. Cumulative backfat accretion by breed from a trial comparing different breeds of swine.

¹AOB category comprised of Hampshire, Landrace, Poland and Spot breeds.

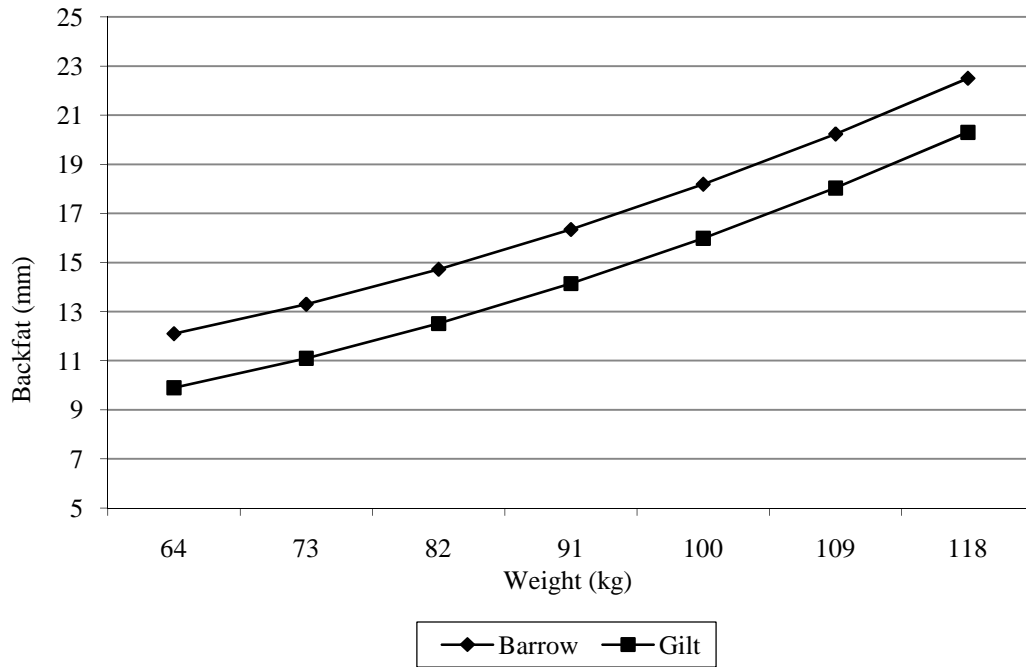


Figure 4. Cumulative backfat accretion by sex from a trial comparing different breeds of swine.

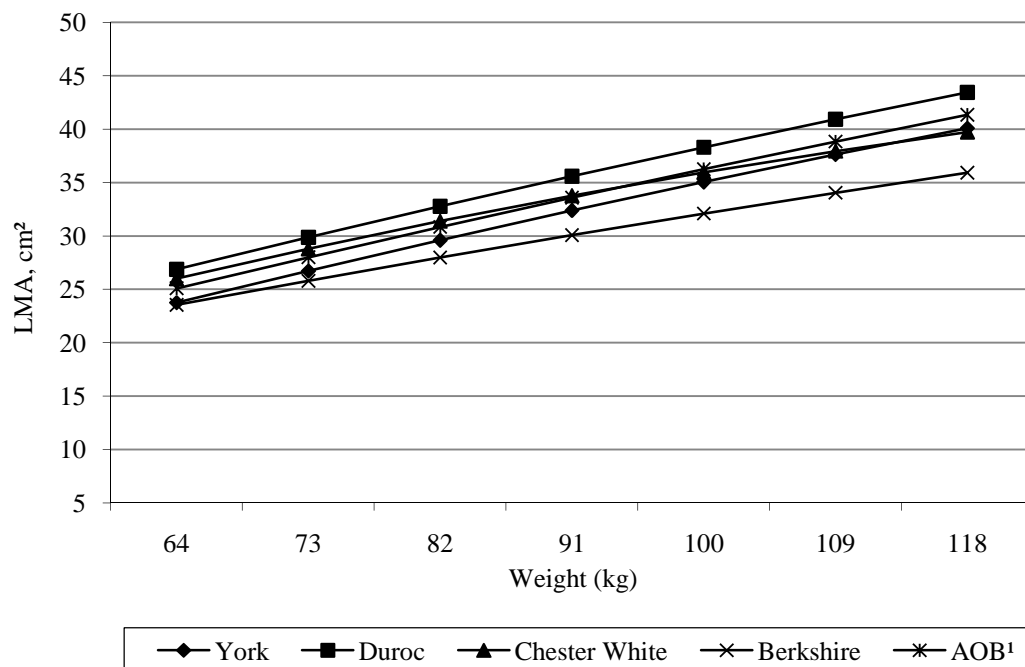


Figure 5. Cumulative loin muscle deposition by breed from a trial comparing different breeds of swine.

¹AOB category comprised of Hampshire, Landrace, Poland and Spot breeds.

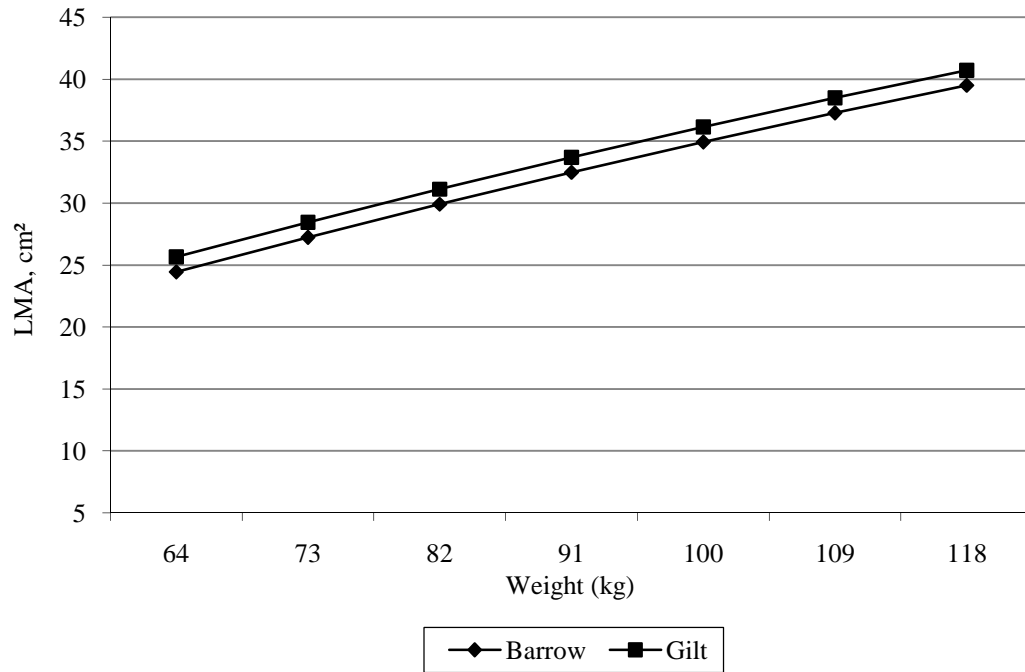


Figure 6. Cumulative loin muscle deposition by sex from a trial comparing different breeds of swine.

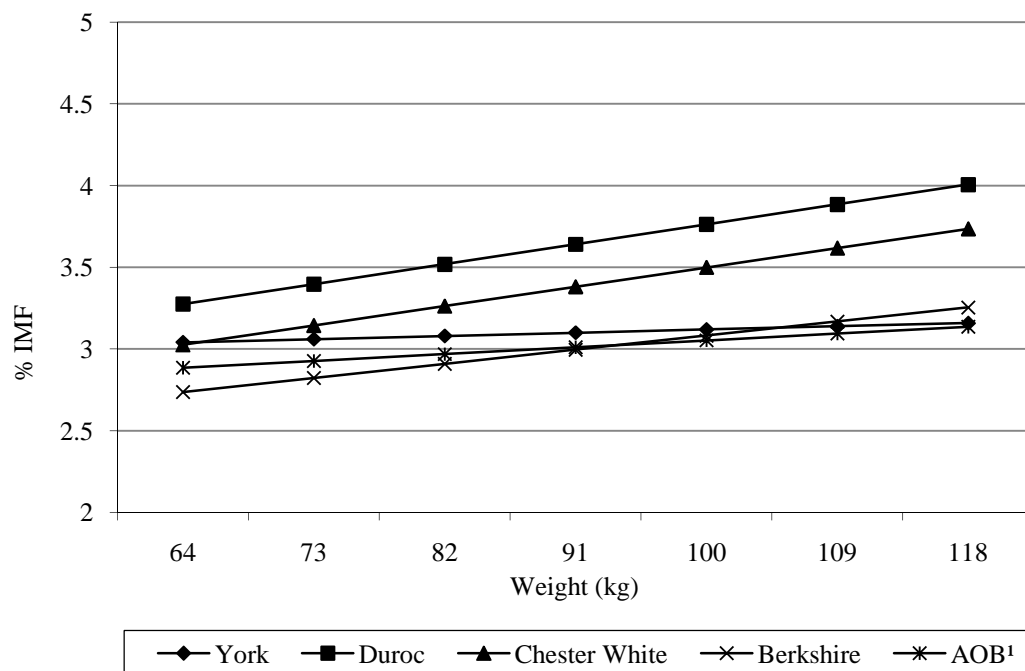


Figure 7. Cumulative longissimus dorsi intramuscular fat deposition by breed from a trial comparing different breeds of swine.

¹AOB category comprised of Hampshire, Landrace, Poland and Spot breeds.

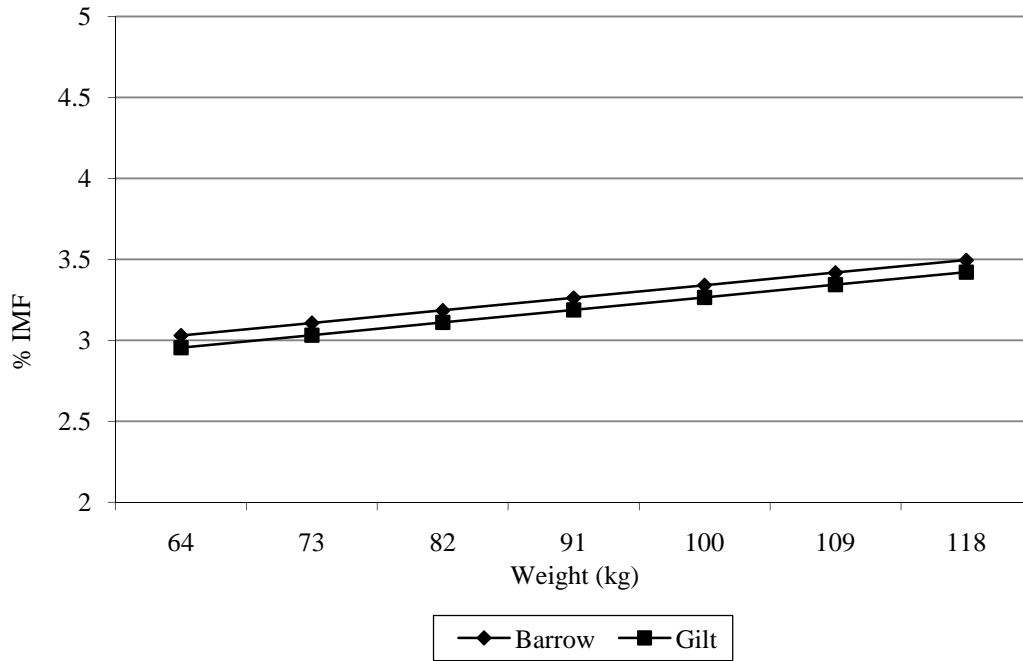


Figure 8. Cumulative longissimus dorsi intramuscular fat deposition by sex from a trial comparing different breeds of swine.

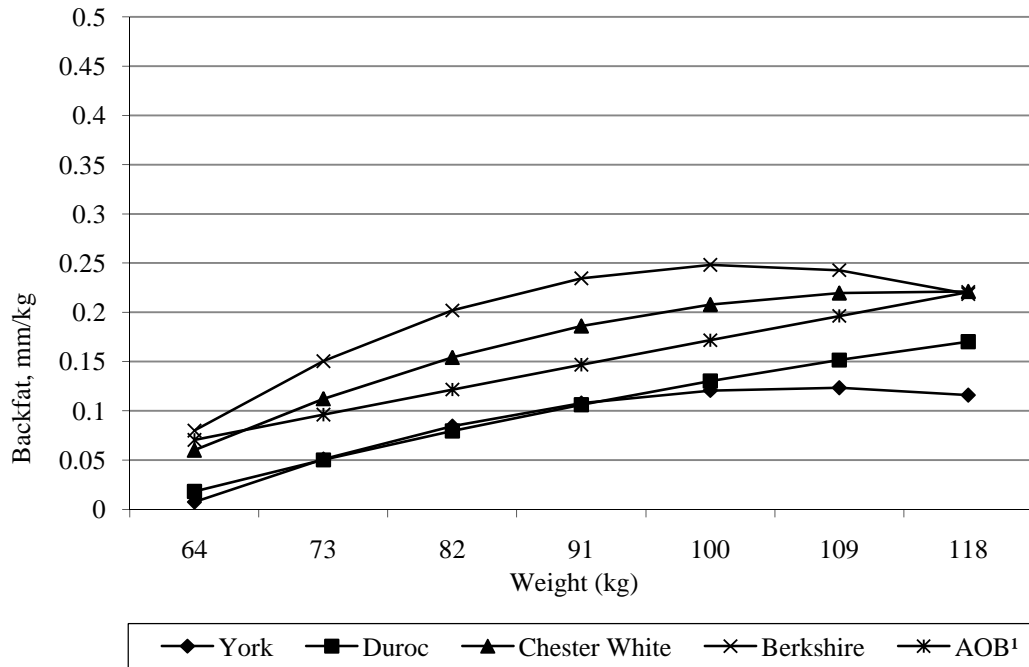


Figure 9. Deposition rate of BF10 per kg of body weight by breed from a trial comparing different breeds of swine.

¹AOB category comprised of Hampshire, Landrace, Poland and Spot breeds.

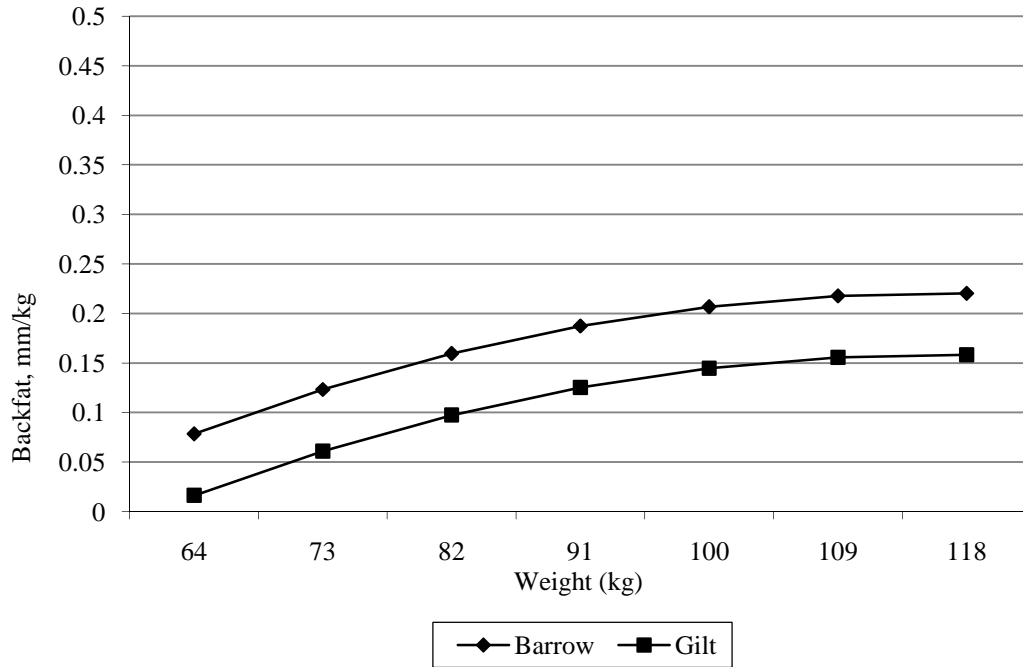


Figure 10. Deposition rate of BF10 per kg of body weight by sex from a trial comparing different breeds of swine.

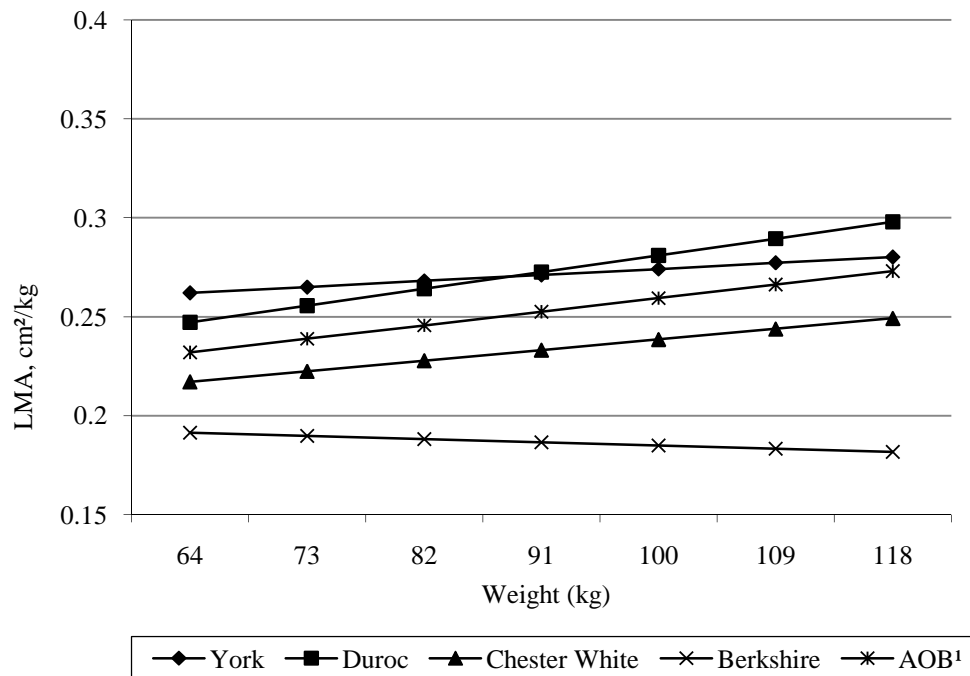


Figure 11. Deposition rate of LMA per kg of body weight by breed from a trial comparing different breeds of swine.

¹AOB category comprised of Hampshire, Landrace, Poland and Spot breeds.

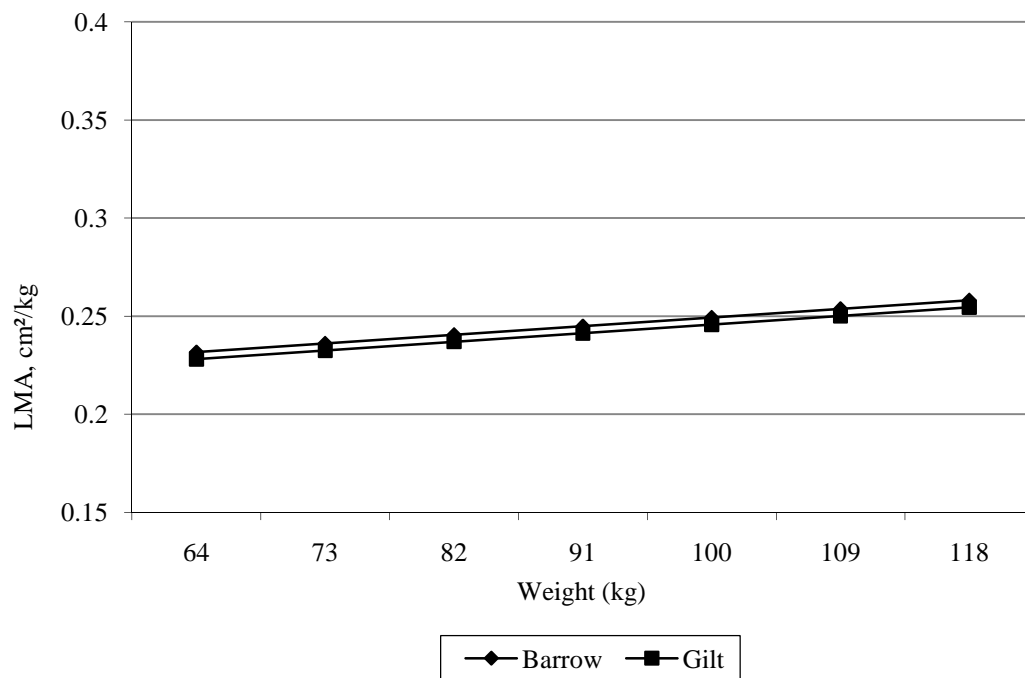


Figure 12. Deposition rate of LMA per kg of body weight by sex from a trial comparing different breeds of swine.

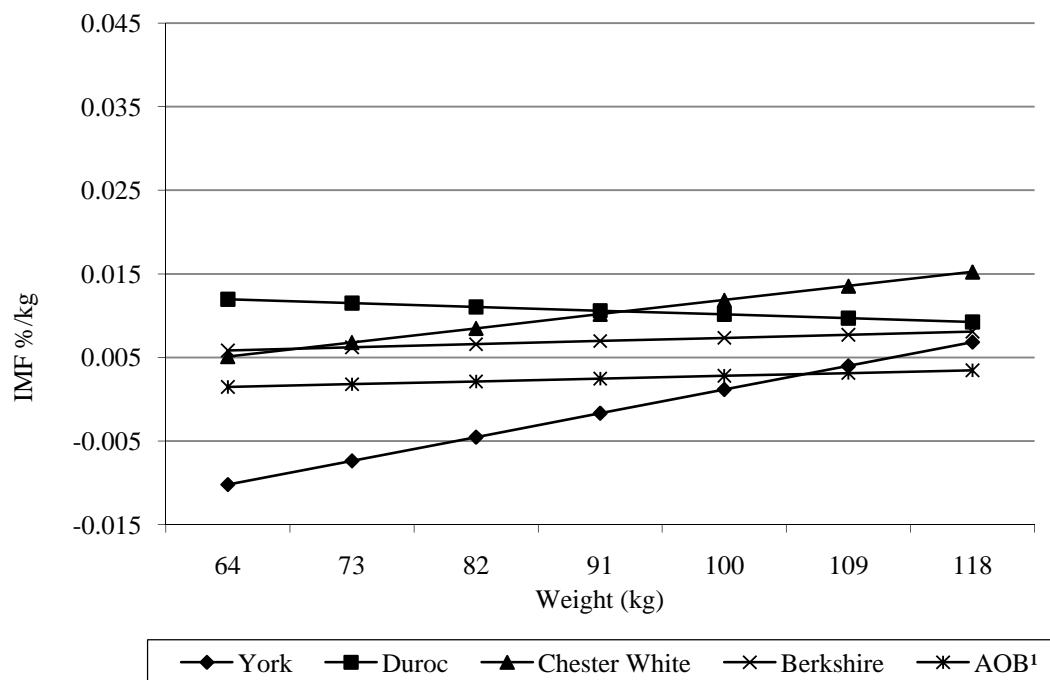


Figure 13. Deposition rate of longissimus dorsi IMF per kg of body weight by breed from a trial comparing different breeds of swine.

¹AOB category comprised of Hampshire, Landrace, Poland and Spot breeds.

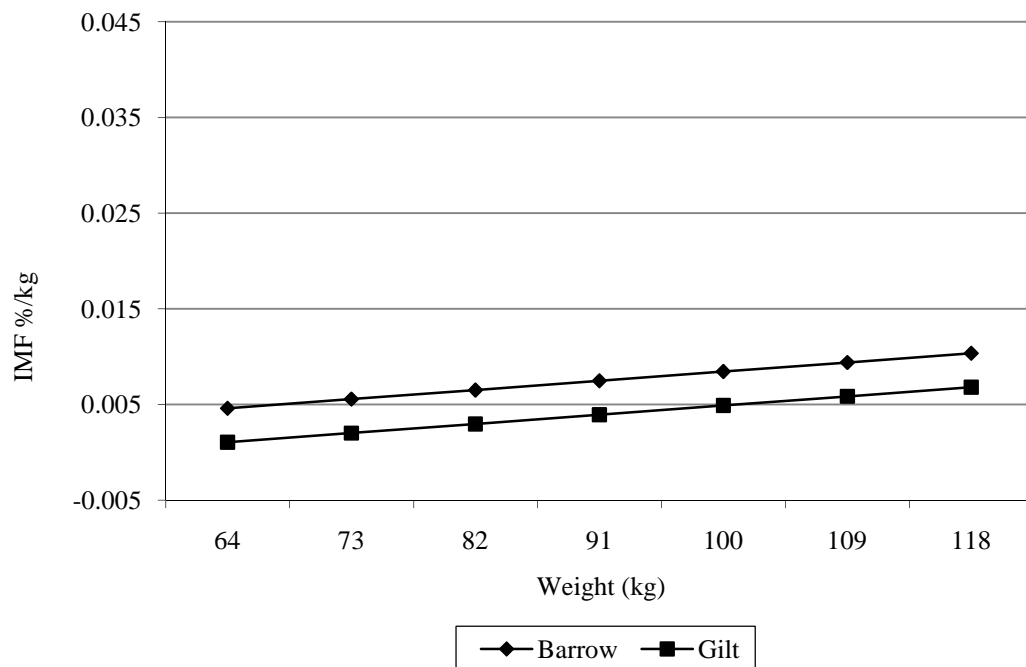


Figure 14. Deposition rate of longissimus dorsi IMF per kg of body weight by sex from a trial comparing different breeds of swine.

GENERAL SUMMARY

The single most important factor in any marketing program is having sufficient demand for the product, and producing a high quality product that will keep the consumer coming back time and again. As the swine industry weighs itself against competitors in the marketplace, namely beef and poultry, it has to address those very questions. The beef industry has a quality grade incorporated into the pricing matrix of the animal. The long term association of pork with a lean matrix pricing system has resulted in a poorer product being delivered to the consumers local meat counter. The problem has reached a point where discerning consumers are willing to pay a premium for niche market pork promising a superior eating experience. As quality has gone down, the short term solution at the packer level has been sorting superior meat quality carcasses from the kill and marking them for export or specific markets. The question remains how long consumer acceptance will stay high enough to meet current supply without these issues being seriously addressed, namely the addition of a quality grade for pork.

Results in the current study show significant variation among breeds for the traits measured. Divergent paths of selection have been tailored to the strengths of each breed, and illustrate how different selection paths can lead to vastly different outcomes as they pertain to lean gain and meat quality. Sufficient genetic diversity exists to make progress in any marketing scenario, and ultrasound has proven as a useful tool in the selection process.

As consumers become more aware and more educated in the process by which their food is produced, attention must be paid to their concerns. The current system has developed enough different markets within the swine industry to begin to tailor more to consumer preferences. As the industry evolves, proper understanding of technology and how to apply it will become even

more important in reaching that goal. The results of this trial should prove useful in those endeavors.

REFERENCES CITED

- Amin, V., D. Wilson, and G. Rouse. 1997. USOFT: An ultrasound image analysis software for beef quality research. A. S. Leaflet R1437. Iowa State University, Ames, IA.
- Baas T. J., L. L. Christian, and M. F. Rothschild. 1992. Heterosis and recombination effects in Hampshire and Landrace swine: II. Performance and carcass traits. *J. Anim. Sci.* 70: 99-105.
- Berger, P. J., L. L. Christian, C. F. Louis, and J. R. Mickelson. 1994. Estimation of genetic parameters for growth, muscle quality, and nutritional content of meat products for centrally tested purebred market pigs. Pages 51–63 in Research Investment Report 1994. Natl. Pork Prod. Council, Des Moines, IA.
- Brorsen, B. W., J. T. Akridge, M. A. Boland, S. Mauney, and J. C. Forrest. 1998. Performance of alternative component pricing systems for pork. *J. Agric. Appl. Econ.* 302:313–324.
- Bruner W. H., and L. A. Swiger. 1968. Effects of sex, season and breed on live and carcass traits at the Ohio Swine Evaluation Station. *J. Anim. Sci.* 27: 383-388.
- Casey, D. S. 2003. The use of electronic feeders in genetic improvement programs for swine. Ph.D. Thesis. Iowa State Univ., Ames, IA.
- Chen, P., T. J. Baas, J. W. Mabry, J. C. M. Dekkers, and K. J. Koehler. 2002. Genetic parameters and trends for lean growth rate and its components in U.S. Yorkshire, Duroc, Hampshire, and Landrace pigs. *J. Anim. Sci.* 80:2062–2070.
- Christian, L. L., K. L. Strock, and J. P. Carlson. 1980. Effects of protein, breed cross, sex and slaughter weight on swine performance and carcass traits. *J. Anim. Sci.* 51:51-58.
- Goodwin, R. N. 2004. Growth, Carcass and Meat Quality Trait Performance of Pure Breeds. Annual Meeting. Natl. Pork Prod. Council, Des Moines, IA. Available: www.nsisf.com/conferences/2004/pdf/RodneyGoodwinPresentation.pdf. Accessed May 15th, 2008.
- Gu, Y., A. P. Schinckel, and T. G. Martin. 1992. Growth, development, and carcass composition in five genotypes of swine. *J. Anim. Sci.* 70:1719–1729.
- Hayenga, M. L., B. S. Grisdale, R. G. Kauffman, H. R. Cross, and L. L. Christian. 1985. A carcass merit pricing system for the pork industry. *Am. J. Agric. Econ.* 67:315–319.
- Herbert, O. J. and R. M. Crown. 1956. Carcass quality characteristics of market barrows and gilts. *J. Anim. Sci.* 15:1269. (Abstr.).

- Hetzer, H. O., J. H. Zeller, and O. G. Hankins. 1956. Carcass yields as related to live hog probes at various weights and locations. *J. Anim. Sci.* 15:257–270.
- Huff-Lonergan, E., T. J. Baas, M. Malek, J. C. M. Dekkers, K. Prusa, and M. F. Rothschild. 2002. Correlations among selected pork quality traits. *J. Anim. Sci.* 80:617–627.
- Johnson R. K., I. T. Omtvedt, and L. E. Walters. 1973. Evaluation of purebreds and two-breed crosses in swine: feedlot performance and carcass merit. *J. Anim. Sci.* 37:18-26.
- Lawrence, J. D., G. A. Grimes, and M. L. Hayenga. 1998. Production and marketing characteristics of U.S. pork producers, 1997-1998. Staff Paper 311. Iowa State University Department of Economics Staff Papers.
- Lawrence, J. D., M. L. Hayenga, T. Schroeder, Evolving Producer-Packer-Customer Linkages in the Beef and Pork Industries, 2001. *Review of Agricultural Economics*, Vol. 23, 2, pp. 370-385
- Lo, L. L., D. G. McLaren, F. K. McKeith, R. L. Fernando, and J. Novakofski. 1992a. Genetic analyses of growth, real-time ultrasound, carcass, and pork quality traits in Duroc and Landrace pigs: I. Breed effects. *J. Anim. Sci.* 70:2373–2386.
- Lo, L. L., D. G. McLaren, F. K. McKeith, R. L. Fernando, and J. Novakofski. 1992b. Genetic analyses of growth, real-time ultrasound, carcass, and pork quality traits in Duroc and Landrace pigs: II. Heritabilities and correlations. *J. Anim. Sci.* 70:2387-2396.
- Lonergan, S. M., K. J. Stalder, E. Huff-Lonergan, T. J. Knight, R. N. Goodwin, K. J. Prusa, and D. C. Beitz. 2007. Influence of lipid content on pork sensory quality within pH classification. *J. Anim. Sci.* 85:1074-1079.
- McLaren, D. G., D. S. Buchanan, and R. K. Johnson. 1987. Individual heterosis and breed effects for postweaning performance and carcass traits in four breeds of swine. *J. Anim. Sci.* 64: 83-98.
- McLaren, D. G., F. M. McKeith, and J. Novakofski. 1989. Prediction of carcass characteristics at market weight from serial real-time ultrasound measures of backfat and loin eye area in the growing pig. *J. Anim. Sci.* 67:1657-1667
- Moeller, S. J., L. L. Christian, and R. N. Goodwin. 1998. Development of adjustment factors for backfat and loin muscle area from serial real-time ultrasonic measurements on purebred lines of swine. *J. Anim. Sci.* 76:2008-2016.
- Murray, A., S. Pommier, L. Gibson, W. Robertson, and M. Johns. 2004. Influence of intramuscular fat (IMF) on pork quality. *Adv. Pork Prod.* 15:16. (Abstr.)

- Newcom, D. W., T. J. Baas, and J. F. Lampe. 2002. Prediction of intramuscular fat in live swine using real-time ultrasound. *J. Anim. Sci.* 80:3046–3052.
- Newcom, D. W., K. J. Stalder, T. J. Baas, R. N. Goodwin, F. C. Parrish, and B. R. Wiegand. 2004. Breed differences and genetic parameters of myoglobin concentration in porcine longissimus muscle. *J. Anim. Sci.* 82:2264–2268.
- Noffsinger, T. L., F. N. Andrews, and V. L. Anderson. 1959. The rate of fat deposition in four lines of swine. *J. Anim. Sci.* 18:127–133.
- NPPC. 1995. Genetic Evaluation/Terminal Line Program Results. R. Goodwin and S. Burroughs, ed. Natl. Pork Prod. Counc., Des Moines, IA.
- Quijandria, B., and O. W. Robison. 1971. Body weight and backfat deposition in swine: Curves and correction factors. *J. Anim. Sci.* 33:911–918.
- SAS Institute, Inc. 1999. SAS/STAT® User's Guide, Version 8. SAS Institute, Inc., Cary, NC
- Schwab, C. R., T. J. Baas, K. J. Stalder, and J. W. Mabry. 2007. Deposition rates and accretion patterns of intramuscular fat, loin muscle area, and backfat of Duroc pigs sired by boars from two time periods. *J. Anim. Sci.* 85:1540-1546.
- Sellier, P. 1998. Genetics of Meat and Carcass Traits. In: *The Genetics of the Pig*. Eds. M. F. Rothschild and A. Ruvinsky. CAB International, 1998. pp.463-510.
- Skelley, G. C., and D. L. Handlin. 1971. Pork acceptability as influenced by breed, sex, carcass measurements and cutability. *J. Anim. Sci.* 32:239-244.
- Smith, B. S., W. R. Jones, J. D. Hough, D. L. Huffman, W. B. Mikel, and D. R. Mulvaney. 1992. Prediction of carcass characteristics by real-time ultrasound in barrows and gilts slaughtered at three weights. *J. Anim. Sci.* 70:2304–2308.
- Stewart, T. S., and A. P. Schinckel. 1989. Genetic parameters for swine growth and carcass traits. *Genetics of Swine*. pp.77-79.
- USDA. 2003. United States of America Country Report for FAO's State of the World's Animal Genetic Resources. Available: http://www.ars-grin.gov/animal/US_SOW_report.pdf. Accessed May 15th, 2008.
- Young L. D., R. K. Johnson, I. T. Omtvedt, and L. E. Walters. 1976. Postweaning performance and carcass merit of purebred and two-breed cross pigs. *J. Anim. Sci.* 42:1124-1132.
- Zohrisky, S. E., Win. G. Moody, L. F. Tribble, and H. D. Naumann. 1961. Meatiness of swine as influenced by breed, season and sex. *J. Animal Sci.* 20:923. (Abstr.).

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