EFFECT OF SIRE LINE AND RATE OF GAIN ON PORK QUALITY

BY

EMILY DANIELLE SCHUNKE

THESIS

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Master's Committee:

Associate Professor Anna C. Dilger, Chair
Associate Professor Ryan N. Dilger
Assistant Professor Bailey N. Harsh
Dr. Chad A. Stahl, Choice Genetics USA

ABSTRACT

Terminal sire selection is a critical factor in modern day swine production as it has the ability to influence characteristics that affect the financial stability of the producer and packer while concomitantly influencing the eating experience of the consumer. Pietrain pigs are often utilized in swine production as they increase feed efficiency and improve both carcass and lean yields whereas, Duroc pigs are known for fast growth and improved overall meat quality. Three experiments were conducted to evaluate the effects of Duroc and Pietrain sire lines on growth performance, carcass cutability, and early and aged pork quality. For these three experiments, the MIXED procedure of SAS was used to evaluate the fixed effects of sire line, sex, and their interactions on pork quality and considered significant at P<0.05. In the first study, an American purebred (**AP**) Pietrain terminal sire line (n=135) was selected for feed efficiency and lean tissue accretion while a European crossbred, 25% Pietrain, (**EC**) terminal sire line (n=114) was chosen for lean tissue accretion and carcass merit. As expected, EC sired pigs had an increased (P=0.03) standardized fat free lean (**FFL**) by 1.63% units. American Pietrain sired pigs had darker loins and chops as early ventral visual color was increased (0.46 units, P<0.001), early ventral L* was decreased (0.89 units, P=0.05), early chop visual color was increased (0.14, P=0.03), and early chop L* was decreased (1.18, P=0.03). Overall, EC sired pigs were leaner, while AP sired pigs had darker (early) loins and chops. In a second experiment, a Duroc terminal sire line (n=160), selected for premium meat quality based programs (**MQ**), was compared to a Duroc terminal sire line (n=144) that was selected for competitive growth and performance (**GP**). Overall (d0-98), GP sired pigs had increased G:F (0.01 kg/d, P=0.03), while MQ sired pigs had darker, heavier marbled loins as early ventral L* was decreased (1.67, P=0.01) and early ventral visual marbling was increased (0.28, P<0.01). Aged ventral visual marbling was increased (0.28, P<0.001) in

MQ sired pigs. Belly thickness and flop were increased (*P*<0.01) by 0.19 cm and 3.5 cm, respectively in MQ sired pigs. Ultimately, GP sired pigs had increased G:F, but MQ sired pigs had improved pork quality. In a third experiment, pigs were sourced from 2 different sire lines of Duroc ancestry. Red (*n*=160) and Green (*n*=160) represented either a P26 Duroc sire line or a competitor Duroc sire line. Overall, Green sired pigs had increased average daily gain (**ADG**; 0.07, kg/d, *P*<0.001), while Red sired pigs had increased FFL (1.31%, *P*<0.01). Loin marbling scores were higher (*P*≤ 0.01) in both the aged ventral (0.48) and chop (0.36) of Green sired pigs. Additionally, Green sired pigs had thicker and firmer bellies as indicated by increased (*P*<0.001) belly thickness (3.97 vs. 3.59) and belly flop (19.64 vs. 15.63). Ultimately, Red sired pigs were leaner leading to greater carcass merit, but Green sired pigs had increased ADG and improved pork quality characteristics. Lastly, pork hot carcass weights (**HCW**) have increased from 82 to 96.5 kg over the last 25 years. As carcasses become heavier, chops become more tender. One possible explanation for this increase in tenderness is increased ADG or growth rates in pigs that reach heavier weights. Therefore, 634 pigs (Duroc or Pietrain sire ancestry) were sourced from 4 separate groups which were raised over two and a half years. Pigs were raised under the same conditions and divided into three groups based on ADG (kg/d) from 12-26wk of age; slow (<0.96kg/d, *n*=96), intermediate (0.96-1.16kg/d, *n*=452), and fast (≥1.17kg/d, *n*=86). Overall ADG was increased (*P*<0.001) in fast growing pigs by 0.15 kg/d. Aged ventral visual color was increased (*P*=0.03) in fast and intermediate growing pigs by 0.23 units. Intermediate growing pigs had firmer loins (*P*=0.04) by 0.07 units. Ventral a* increased as growth rate increased (*P*=0.04) indicating fast growing pigs had the reddest loins (9.77 vs. 9.26 vs. 8.99). Instrumental tenderness did not differ (*P*=0.51) between growth rate groups. While faster growth rates improved aged ventral visual color, instrumental tenderness did not differ between groups.

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CHAPTER 1: REVIEW OF THE LITERATURE

INTRODUCTION

The United States is a large contributor to the world's pork supply as it is the third-ranked country in total pork production and produces over 10% of the world's pork (National Pork Board, 2017). Additionally, the U.S. is second in total world pork exports and is responsible for approximately 29% of the world's pork exports (National Pork Board, 2017; USMEF, 2019). While domestic markets are extremely important, export marketing opportunities also play a significant role in pork production as said markets can add significant value to carcasses when compared to domestic prices. For the United States, there is value in exporting carcasses, carcass primals, or offal in large volumes to some countries, but there is also value in exporting targeted, high-quality cuts to others. At the end of 2019, the value of a commercial pig destined for export in the U.S. was increased by $66.70 per head as compared to being sold on the domestic market (USMEF, 2019). That being said, it is important to keep in mind that export markets differ, as consumers in various countries perceive "quality" very differently.

In 2019, the top importers of U.S. pork were Mexico, Hong Kong/China, and Japan (USMEF, 2019). Mexico imported the most pork on a volume basis, whereas China imported the most offal and variety meat, and Japan imported the most on a value basis (USMEF, 2019). In Mexico, consumers prefer light colored pork cuts with less intramuscular fat (Lowell, et al., 2019). China is rather unique such that most of their products are purchased on wet or open markets therefore, consumer preference data is rather limited; however, one study reported consumers prefer a light red, lean product (Grunert, et al., 2015). Japanese consumers prefer high quality, dark-colored, and highly-marbled primal cuts (Lowell et al., 2019; Suzuki et al., 2005).

Given the different goals needed to meet the demands of these markets, proper sire line selection is key.

Pietrain and Duroc terminal sires are commonly used in commercial swine production systems as they target different markets, which meet various consumer demands. Pietrain sired pigs are known for being feed efficient and increasing carcass and lean meat yields (Lowell, 2019). On the contrary, Duroc-sired pigs are fast growing and utilized in scenarios in which pork quality is of high value as they are known for improving ultimate pH, marbling, and water-holding capacity (Edwards et al., 2003b; Lowell et al., 2018). That being said, Pietrain terminal sire lines can be used to target Mexican and Chinese export markets as consumers prefer lean product. Duroc terminal sire lines can target Japanese export markets as those consumers value product of improved pork quality.

Therefore, the objective of this literature review is to evaluate early and aged pork quality characteristics of Pietrain and Duroc terminal sire lines in order to suffice consumer preferences of different markets. This literature review will also encompass the effects of growth performance, carcass characteristics, and carcass composition between the two different breeds.

Furthermore, the USDA recently reported that over the last 25 years, pork hot carcass weights (**HCW**) have increased from 82 to 96.5 kg (USDA, 2019). This change in pork HCW witnessed by the packing industry directly affects the profitability of both producers and packers. With that, this literature review will also review the effect of increasing HCW on early and aged pork quality characteristics.

CARCASS CHARACTERISTICS

Typically, pork HCW and standardized fat-free lean percentage (**FFL**) are the key components used to determine the economic value of a pork carcass by packers. Standardized

FFL is largely affected by back fat depth, which can be measured by probes between the 3rd/4th rib to the last rib. There are multiple procedures that can be used by packers and researchers in order to determine FFL (Burson & Berg, 2001). For ribbed carcasses, FFL is calculated by using the equation, (8.588 + (0.465 × HCW, lb) – (21.896 × 10th rib fat thickness, in) + (3.005 × 10th rib loin muscle area, in^2)) / HCW, lb) × 100. However, it is important to note that carcasses are normally not ribbed in industry settings by packers, but rather for research purposes. Carcasses are normally unribbed in which FFL can be calculated using the equation, (23.568 + 0.503 × (HCW, lb) – 21.348 × (last rib back fat thickness, in.)). A Fat-O-Meter can also be used to determine FFL using the equation, (15.31 + 0.51 × (warm carcass wt., lb.) – 31.277 × (last rib back fat thickness, in.) + 3.813 x (loin muscle depth, in.)).

While HCW and FFL are the most common carcass characteristics valued by the packer, carcass yield can also be calculated. Carcass yield is calculated by dividing HCW by ending live weight (**ELW**) and is expressed as a percentage. During recent years, live hogs and pork carcasses have gotten heavier thusly-influencing total carcass yield. In 2019, the ELW of domestic hogs was reported to be approximately 130 kg, which yields a 97.5 kg carcass with approximately 1.4-1.8 cm back fat at the last rib, a 55-56% FFL, and a 75% carcass yield (USDA Economic Research Service, 2020; USDA, 2020).

CARCASS COMPOSITION

Generally speaking, carcasses are composed of bone, muscle, fat, and skin, each of which has its own innate value as determined by consumers with differing wants, tastes, and preferences. Keeping that in mind, carcass composition can and often is evaluated in multiple ways. Traditionally, most processors further fabricate pork carcasses into shoulders (butts and picnics), loins, hams, and bellies. Currently, of an entire carcass, loins make up 25.12%, butts are

10.27%, picnics are 11.25%, spareribs are 4.66%, hams are 24.56%, and bellies are 16.43% of an entire carcass (USDA, 2020). Additionally, bone-in lean cutting yield, bone-in carcass cutting yield, and boneless carcass cutting yield, can be determined using the following equations (Lowell et al., 2019):

Bone-in lean cutting yield, % = [(trimmed ham (NAMP #402), kg + bone-in trimmed Boston butt (NAMP #406), kg + bone-in picnic (NAMP #405), kg + trimmed loin (NAMP #410), kg) / chilled left side weight, kg]×100

Bone-in carcass cutting yield, % = [(bone-in lean cutting yield components + natural fall belly (NAMP #408), kg) / chilled left side weight, kg] × 100

Boneless carcass cutting yield, % = [(inside ham (NAMP #402F), kg + outside ham (NAMP #402E), kg + knuckle (NAMP #402H), kg) + inner shank, kg + lite butt, kg + Canadian back (NAMP #414), kg +tenderloin (NAMP #415A), kg + sirloin (NAMP #413D), kg) + boneless Boston butt (NAMP #406A), kg + boneless picnic (NAMP #405A), kg + natural fall belly (NAMP #408), kg)) / chilled left side weight] × 100

PORK QUALITY

Consumer interpretation and subsequent definition of "pork quality" changes as you move throughout the globe, in part due to varying preferences and purchasing decisions found amongst different countries. In the United States, visual color and marbling are what drive consumer purchasing decisions (Moeller et al., 2010). That said, we know that multiple traits influence pork quality, which in general, is assessed on the loin. These include but are not limited to color, marbling, tenderness, juiciness, and flavor (Moeller et al., 2010; Ngapo et al., 2007).

Ultimate pH

The process of exsanguination causes a loss of circulation therefore muscles no longer have access to oxygen and cannot regulate body heat or remove waste. Due to lack of oxygen, muscles transition into anaerobic metabolism, which requires ATP; however, in the anaerobic state, ATP production is rather hard as energy is limited. Through the process of glycolysis, pyruvate is converted to lactate. With the loss of circulation, muscles lose the ability to maintain cell membrane integrity thus causing a calcium influx. In turn, the muscles will contract. Stored glycogen in the muscle is broken down into pyruvate which is then further broken down into lactic acid. However, without circulation, there are no means to remove lactate and therefore, it accumulates in the muscle thus, causing a build-up of hydrogen ions (H^+). This in turn causes pH to decline from 7.2 to an ultimate pH of 5.6 in 24 h (Matarneh, et al., 2007). Extent of pH decline is dependent upon the availability of stored glycogen within a muscle at the time of slaughter. Ultimate pH is important as it has been shown to significantly influence many quality characteristics including water-holding capacity (**WHC**), color, and tenderness (Boler et al., 2010). Atypical extremes in ultimate pH are often associated with two product defects that occur in the packing industry: pale, soft, and exudative (**PSE**) meat and dark, firm, and dry (**DFD**) meat. The combination of rapid pH decline and elevated temperatures of muscle postmortem result in PSE meat whereas a limited pH decline results in DFD meat. The ultimate pH of normal meat ranges from 5.5-5.7 whereas meat with an ultimate pH below 5.4 would be considered PSE meat and meat with an ultimate pH above 6.0 is considered DFD meat (Adzitey & Nurul, 2011, Matarneh, et al., 2007). Ultimate pH greatly influences color more specifically as it reaches the isoelectric point (5.2) such that lean tissue becomes pale colored negatively impacting consumer appeal (Boler et al., 2010). This happens by means of rapid pH decline and higher body temperatures, which leads to protein denaturation and decreased WHC.

Water-holding Capacity

Lean tissue is approximately 75% water, which is held within the myofibrils of the muscle cell (Huff-Lonergan & Lonergan, 2005). Three types of water occur within lean tissue and all influence WHC. Bound water is bound to proteins and tightly held within lean tissue. Immobilized water is held more loosely, but their charges are bound with water and each other. Free water has the ability to move as it pleases, but only the capillary system has the ability to hold this water in place.

As previously mentioned, it is possible for pH to reach an isoelectric point of 5.2 where the positive and negative charges of the protein are attracted to each other, but the protein cannot hold those charges (Huff-Lonergan & Lonergan, 2005). This causes an inability for the protein to bind and retain water. Therefore, the WHC of protein is improved as ultimate pH moves further away from the isoelectric point. This can be determined by various means including drip loss, purge loss, or cook loss methods.

Color

Consumers deem visual color as being indicative of overall freshness and quality, thus most make their purchasing decisions accordingly (Mancini & Hunt, 2005). As previously stated, both ultimate pH and WHC influence color making all of these traits somewhat dependent upon one another. Myoglobin is the heme iron that gives meat its red color. Myoglobin will go through partial denaturation when pH declines at a fast rate causing paler colored lean muscles however, carcasses with higher ultimate pH have darker colored lean muscles that retain more water (Huff-Lonergan et al., 2002). Fresh pork color can be measured both subjectively (NPPC color score) and (or) objectively (instrumental color score). NPPC color scores consist of a scale of 1-6 with 1 being extremely pale and 6 being extremely dark whereas instrumental color is a means by which color can be objectively quantified using a range in numbers. One way of measuring objective color is to utilize a Minolta Chromameter which outputs color values using a Commission Internationale de l'Eclairage (CIE) scale of L* a* and b*. Instrumental L* is a measurement of lightness on a scale of 0 (black) to 100 (white) meaning that lower L* values would indicate darker colored loins as compared to increased L* values would indicate paler colored loins. One study reported a 5 unit difference in L* has the ability to impact a consumers purchasing decision (Norman et al., 2003). Increased a* values indicate redder loins as instrumental a* is a measurement of redness on a scale of -60 (green) to 60 (red). Additionally, a greater b* indicates more yellow loins as instrumental b* is a measurement of yellowness on a scale of -60 (blue) to 60 (yellow).

In addition to ultimate pH and WHC, myoglobin content, the current state of myoglobin, and muscle fiber type also contribute to fresh pork color. As previously mentioned, myoglobin is the pigment protein primarily responsible for the red color associated with meat. Hemoglobin and cytochrome also contribute to pork color yet to a lesser extent as they can be trapped in arteries and veins (Suman & Joseph, 2013). The state of myoglobin depends upon the state of iron which can either be reduced (ferrous/Fe^{2+}) or oxidized (ferric/Fe^{3+}); (Suman & Joseph, 2013). Myoglobin can exist in any of the four redox states and all contribute to lean color in their own respective way (Mancini & Hunt, 2005). Consumers generally prefer the oxymyoglobin and carboxymyoglobin forms of myoglobin due to a cherry-red appearance where the heme is reduced (Mancini & Hunt, 2005). Deoxymyoglobin is also a reduced heme, yet unlike both oxymyoglobin and carboxymyoglobin, the color is purple in appearance (Mancini & Hunt, 2005). The fourth and final form of myoglobin is metmyoglobin which has an oxidized heme and appears brown (Mancini & Hunt, 2005).

In general, muscles are often classified as being red or white based upon their muscle fiber composition. Although muscles are generally referred to as one or the other in terms of color, most muscles are a combination of both fibers (Aberle et al., 2012). In general, oxidative fibers are termed red fibers as they have a high myoglobin content, have an increased lipid content, and are found in endurance muscles as they contract slowly. Glycolytic muscle fibers have a decreased myoglobin content thus, they are referred to as white fibers. Additionally, glycolytic fibers have a decreased lipid content and are found in power type muscles as they are known for fast contraction. There are four types of muscle fibers; type I (red, oxidative, and slow), type IIA (red, oxidative and glycolytic, and fast), type IIX (white, glycolytic, and fast), and type IIB (white, glycolytic, and fast); (Lee et al., 2010).

Marbling

Intramuscular fat (**IMF**) or marbling is defined as fat within an actual muscle that is stored as droplets within muscle fibers. Marbling can be evaluated subjectively by a trained personnel using standards set forth by the NPPC in which marbling scores range from 1 to 10; 1 being equivalent to 1% intramuscular lipid content and 10 equaling 10% intramuscular lipid content (NPPC, 1999). Extractable lipid percentage can be determined by means of a solvent method such that the solvent extracts lipid from lean tissue and the extractable lipid is expressed as a percentage. Marbling is a moderately heritable trait and can be influenced by antemortem production factors including breed types and diet rations. Typically, hogs are bred with the intentions of being utilized for lean type markets or meat quality type markets. In general, lean type pigs have less intramuscular fat and extractable lipid when compared to meat quality type pigs (Ellis et al., 1996).

Marbling is often associated with the quality of eating experience as IMF positively influences tenderness, juiciness, and flavor (Brewer et al., 2001; Hocquette et al., 2010). Thusly, intramuscular fat is often associated with an acceptable eating experience as marbling has been significantly correlated with tenderness (Huff-Lonergan et al., 2002). Consequently, greater amounts of marbling should result in decreased shear force values (more tender). However, recent work has concluded that marbling may not be indicative of overall consumer eating experience, more specifically tenderness, as it was once thought to be (Richardson et al., 2018; Wilson et al., 2017). Additionally, one study determined marbling was not correlated with juiciness (Huff-Lonergan et al., 2002).

It has been reported that a minimum of 3% intramuscular fat is needed in order for consumers to rate pork as acceptable and palatable (Savell et al., 1988). Another study reported that once IMF levels were above 2.5%, flavor and juiciness were significantly enhanced (Fernandez et al., 1999). A benchmark study by the National Pork Board determined that the average marbling score of center-cut pork loin chops found in the store currently is 2.30, based on NPPC standards (Newman, David, 2017).

Sensory Characteristics

Historically, consumers use both color and marbling to forecast their overall eating experience, and more specifically tenderness and juiciness (Lonergan et al., 2007; Wood et al., 2004). Repeat purchase behavior is extremely valuable in the meat packing industry and sensory characteristics (tenderness, juiciness, and flavor) often factor into these purchasing decisions. Consequently, it is important that scientists are able to measure and quantify the aforementioned sensory characteristics. To do so, both trained taste panelists or consumer panelists are utilized. In addition to panelists, tenderness can be measured by instrumental means using slice shear force (**SSF**) or Warner-Bratzler shear force (**WBSF**) method. Instrumental tenderness measures the amount of force needed to break through muscle fibers mimicking human chewing therefore, as shear force values increase, meat is considered less tender. If chops have a shear force value of ≤ 4.4 kg for WBSF or ≤ 20.0 kg for SSF they are considered tender (ASTM, 2018). Additionally, when the change in shear force value is greater than 0.5 kg for WBSF or 4.6 kg for SSF, consumers are able to detect the difference (ASTM, 2018).

Degree of doneness or endpoint cooking temperature is known to significantly influence both juiciness and tenderness (Moeller, et al., 2010). In years past, it was recommended that pork loin chops be cooked to a final internal endpoint temperature of 71˚C due to the risk of *Trichinella spiralis.* However, production practices have changed over the years ultimately reducing the risk of contracting the parasite. These changes include moving pig production indoors, tightening biosecurity measures, and managing diet rations to only include milled feed. Therefore, the National Pork Board decreased the recommended endpoint cooking temperature of pork from 71˚C to 63˚C in 2011. A recent study conducted at the University of Illinois compared degree of doneness and pH on sensory characteristics (Honegger et al., 2019). A panel of consumers evaluated sensory characteristics of pork loin chops at varying degrees of doneness and determined ultimate pH has minimal effects on those characteristics except for juiciness such that it increases with ultimate pH. Nevertheless, the findings demonstrated that a lower final endpoint cooking temperature reflected increased tenderness, juiciness, and flavor scores amongst consumers as opposed to increased pH.

HAM QUALITY

Though most pork quality measurements are collected from the loin, other primal cuts contribute to the value of pork carcasses and must be evaluated separately. Despite also being a lean cut, ham quality and loin quality are not correlated (Arkfeld et al., 2016). Domestically, fresh pork hams are generally dry cured, smoked, or further processed before reaching the consumer as opposed to selling fresh, uncured ham and ham products. With that, the extent of literature measuring fresh ham quality characteristics in the United States is relatively limited in comparison to both the loin and belly. However, for extended shelf life purposes, it has been recommended that the semimembranosus (**SM**) muscle of a fresh ham with increased IMF levels and an ultimate pH above 5.5 be used for dry cure ham production (Peloso et al., 2010). Historically, when assessing ham quality, ultimate pH and objective color by means of L*, a*, and b*, are the most commonly evaluated quality characteristics. The SM or inside ham muscle is used most often in literature to evaluate objective color measurements (Boler et al., 2011). Additionally, one report argues the best indicator of overall ham quality is ultimate pH measured in the SM of a fresh ham at 24 hours post exsanguination (Alviset et al., 1995, Boutten et al., 2000).

Supply chain benchmarking research conducted by Person et al (2005) evaluated the SM of fresh hams for instrumental color (L*, a*, and b*) and ultimate pH. In this particular analysis, the SM of fresh hams were evaluated for instrumental color score (L* = 59.19, a* = 6.95 and b* =11.05) and ultimate pH (6.02). A separate study conducted six years later evaluated instrumental color (L*, a*, and b*) and ultimate pH of the SM from pigs fed ractopamine versus a control group (Boler et al., 2011). Instrumental color scores for the control group were 47.47, 9.74, and 3.27, respectively, with an ultimate pH of 5.71. While these studies were different from each other in their own right, instrumental color scores were very different between studies suggesting that more research is needed to better understand fresh ham quality.

Within fresh pork hams, it is not uncommon to see two-toning which is due to a contrast in pigmentation within the muscles of the ham (McKeith & Pringle, 2013). It has also been suggested that two-toning could possibly be due to the amount of myoglobin in adjacent muscles. However, one study argues that a better possible explanation for the two-toning phenomenon seen in ham muscles is the size and number of muscle fibers in adjacent muscles (McKeith & Pringle, 2013). A study compared two-toned hams with normal hams and determined normal hams have a significantly higher ultimate pH of the gluteus medius at 24 hours by 0.12 units (McKeith & Pringle, 2013). This study also measured instrumental color (L*, a*, and b*) of the SM and determined normal hams had significantly darker, more red, and less yellow SM muscles than two-toned hams. Overall, this study concluded ultimate pH was most strongly related to the two-toning phenomenon seen in hams as opposed to other characteristics evaluated. A separate study sorted hams by instrumental L* values of a specified zone within a ham muscle (Stufft, et al., 2016). It was determined that within the dark ham group, myoglobin content was increased in the specified region when compared to lighter colored regions. Although these hams were not considered two-toned, the difference in myoglobin content between dark and light colored regions within one ham does suggest that myoglobin content could be a possible explanation for the two-toning phenomenon.

BELLY QUALITY

Belly quality can be defined differently by the consumer or the processor. Recently, the consumer has driven the demand for leaner bellies as consumers are willing to pay more for uniform slices with a higher lean to fat ratio (Soladoye et al., 2015; Wright et al., 2005). Although the consumer is willing to pay more for leaner bacon, processors value thicker bellies as they often lead to increased slicing yields and higher profits as compared to thinner bellies

(Person et al., 2005). With increased consumer demand for leaner bellies, packers lost nearly $97 million in revenue due to decreased product yields from thin bellies in 2005 (Wright et al., 2005). The loss in revenue promoted the importance of measuring belly thickness as it has the potential to be indicative of processing yields. A sharpened probe is inserted into designated midpoints along the latitudinal and longitudinal axis of the belly in order to measure thickness.

Historically, as pigs become leaner, belly composition is compromised. This can be partially attributed to an increase in polyunsaturated fat (**PUFA**) concentrations and decreased saturated fatty acid (**SFA**) concentrations which in turn, affect production and slicing yields (Person et al., 2005; Soladoye et al., 2017). Reductions in slicing yields are of concern for the processor as this negatively affects overall profitability. Fat firmness is an important characteristic that can be assessed by means of belly flop or evaluating the proportion of SFA. The belly flop test is performed in which bellies are typically placed over a v-shaped smoke stack bar and the greater the distance between the ends of the belly, the firmer the belly. It is possible that longer bellies have more impact on belly flop scores such that they are heavier and the impact of weight will increase bending of the bellies (Soladoye, et al., 2017). Iodine value (IV) can also be measured as a means to determine overall carcass firmness and therefore, belly firmness. A sample from the belly is evaluated to determine the percentage of unsaturation of a fatty tissue thusly as percentage of unsaturated of fatty acids decreases, the more firm the belly is considered to be.

As fresh bellies are further manufactured into cured bellies and then sliced into bacon, many characteristics are evaluated including pump uptake percentage, cooked yield percentage, and sliced yield percentages. Additionally, individual bacon slices are commonly evaluated for quality parameters. Although a standard grading system for bacon slices is nonexistent, processors tend to classify slices as grade 1 or grade 2 which is dependent upon overall uniformity, lean to fat, and consumer appeal (Soladoye et al., 2017). Individual slice lean to fat can be measured using Adobe Photoshop CC 2018 (Adobe Systems Inc., San Jose, CA) as lean to fat areas can be individually outlined and measured (Lowell et al., 2019). Additionally, this software analysis is able to measure length, width, and total area of each individual slice.

Quantifying an "acceptable" belly thickness or firmness is rather hard as this value is absent in present literature. However, one review sorted bellies into three groups; thin (approximately 2.0 cm), average (approximately 2.5 cm), and thick (approximately 3.0 cm) belly thicknesses (Person et al., 2005). This study determined that bellies within the "thick" group had the highest slicing yields. As expected, "thin" bellies produced the largest percentage of #2 slices, comparable to grade 2 slices and were considered of lesser value.

RATE OF GAIN

As previously mentioned, pork HCW have increased over the last 25 years (USDA, 2019). Heavier carcasses can be attained by heavier birth weights, weaning weights, or increased growth rates. A previous study evaluated varying growth rates in pigs and determined that fast growing pigs consistently had heavier body weights from birth to 170 days, increased ADG from birth to finishing, and heavier carcasses when compared to average and slow growing pigs (He et al., 2016). Throughout this study the majority of pigs with light birth weights remained in the slow growth category from birth to finishing and needed an extra 10 to 14 days to reach final market weight, on average, when compared to pen mates (He et al., 2016). It is possible that slow growing pigs which remain in that category did not receive an adequate amount of milk and colostrum at birth; therefore, they lacked the essential amount of nutrients needed to thrive (He et al., 2016; Mahan & Lepine, 1991). Additionally, it is possible that slow growing pigs have less muscle fibers in general therefore, limiting their capability of muscle growth as compared to average and fast growing pigs (He et al., 2016; Rehfeldt et al., 2000). Additionally, this study determined that fast growing pigs had more back fat and larger loineye areas when compared to average and slow growing pigs (He et al., 2016). Therefore, it is possible to conclude that early weights (birth and weaning) and average daily gain of pigs could be related.

One study evaluated the effects of increased HCW, which ranged from 53 to 129 kg, on early and aged pork quality (Harsh et al., 2017). Overall, at 1 d postmortem, heavier carcasses had lower ultimate pH values, but interestingly enough, loins from heavy carcasses were darker (instrumental L*) and redder (instrumental a*; $P<0.0001$). At 20 d postmortem, loins were darker as instrumental L* values decreased and subjective visual color scores increased as HCW increased ($P\leq0.01$). Additionally, loins were firmer ($P<0.0001$) at 1 d and 20 d postmortem as subjective firmness scores increased as HCW increased. At 20 d postmortem, subjective visual marbling scores increased ($P<0.01$) as HCW increased indicating loins from heavier carcasses were heavier marbled. Finally, as carcass weight increased, chops became more tender as evident by a decrease in SSF, however HCW only attributed 3% of variation in SSF. Additionally, as HCW increased, overall cook loss decreased ($P<0.001$).

Additionally, a separate study also evaluated the effects of increased HCW, which ranged from 78 to 145 kg, on early and aged pork quality (Price et al., 2019). It was determined that heavier carcasses exhibited an increase in back fat ($P<0.001$) ultimately leading to a decrease ($P<0.0001$) in estimated lean. As HCW increased, at 1 d postmortem, instrumental b* increased ($P<0.01$) indicating loins from heavier carcasses appeared more yellow. Excluding instrumental b*, there were no other observed effects on early quality characteristics as HCW increased ($P\geq0.13$). As carcass weight increased, SSF decreased thus, chops became more tender, however

HCW only attributed 8% of variation in SSF. Additionally, as HCW increased, overall cook loss decreased (P<0.0001). Based upon the findings of the two previously mentioned studies, it could be concluded that heavier carcasses result in more tender chops.

As carcasses are becoming heavier, many characteristics, both antemortem and postmortem, are affected. In addition to the importance of feed conversion, a review of heavy weight pigs emphasized the importance of utilizing sire lines selected for lean growth in order to extend adequate weight gain during growth without detrimentally impacting meat quality (Wu et al., 2017). This review reported values based upon an average of multiple studies in which pigs were raised to heavier weights with the ultimate goal of predicting how certain characteristics would change as market pigs increased in weight by 10 kg (Wu et al., 2017).

In terms of growth performance, as pigs get heavier, it was estimated that ADG decreased by 0.004 kg/d and ADFI increased by 0.08 kg/d. Given that the greatest input cost that a swine producer incurs is feed expense, such an increase in ADFI is concerning. This highlights the need for increases in overall feed efficiency. When carcass characteristics were evaluated, carcass yield, back fat, and LEA increased by 0.41%, 0.18 cm, and 1.8 cm^2, respectively; however, FFL decreased by 0.78% units. Additionally, as pigs got heavier, belly yields increased by 0.32%, but loin, shoulder, and ham yields decreased by 0.13%, 0.16%, and 0.17%, respectively. Finally, in terms of pork quality, L*, ultimate pH, and drip loss decreased by 0.25 units, 0.01 units, and 0.11%; however, a*, b*, and WBSF increased by 0.30 units, 0.05 units, and 0.06 kg.

PIETRAIN AND DUROC TERMINAL SIRE LINES

Growth Performance of Pietrain and Duroc-Sired Pigs

In general, growth performance and feed efficiency are traits of high economic value and considered moderately heritable (Mote & Rothschild, 2020). Historically, there are minimal studies that directly compare overall growth performance between Duroc and Pietrain-sired pigs during finishing. However, it has been relatively well established that Pietrain-sired pigs are often selected in commercial swine production as they improve feed efficiency and increase both carcass and lean yields (Werner et al., 2010); whereas Duroc-sired pigs are selected to improve meat quality, but have been noted for fast growth performance (Gil et al., 2008; NPPC, 2011).

Recently, a study at the University of Illinois evaluated Duroc and Pietrain-sired pigs throughout a 3-phase finishing system (Lowell et al., 2019). The Duroc terminal sire was selected for a combination of both growth performance and meat quality traits while the Pietrain terminal sire was selected for feed efficiency and lean tissue accretion. Birth weight did not differ between the two different sire lines, but Duroc sired pigs were heavier (P<0.001) at weaning by 0.63 kg compared to Pietrain sired pigs. It was determined that during phase 1 (d0-35), Pietrain-sired pigs had increased (P<0.001) G:F by 0.02 kg and during phase 3 (d71-98), Duroc-sired pigs had increased (P<0.01) ADFI by 0.21 kg/d. While the increase in G:F was relatively small, Pietrain-sired pigs did in fact have increased performance during phase 1, based off the trait they were selected for; however, Duroc-sired pigs were not superior in growth performance which is interesting as that was the trait they were selected for.

In a separate study, growth performance of Duroc and Pietrain-sired pigs were evaluated and while some pigs were either immunologically castrated, surgically castrated, or left intact, it is important to note that data being referenced only represents the effect of sire line (Morales et al., 2013). This study found that Duroc-sired pigs exhibited increased (P<0.001) ADG from days 87 to 137, 137 to 164, and overall by 0.20, 0.15, and 0.18 kg/d, respectively (Morales et al., 2013). It is plausible that the conflicting conclusions presented is due to a lack of comparative growth performance data of Duroc and Pietrain sire lines and/or because of the vast genetic improvement in both the Duroc and Pietrain lines over the last decade. Nevertheless, it is apparent that more research is needed to better understand the growth performance of these sire lines when utilized within modern production programs.

Carcass Characteristics and Composition of Pietrain and Duroc-Sired Pigs

Though there are limited studies directly comparing Duroc and Pietrain pigs, in general, Duroc pigs are fatter than Pietrain pigs (Edwards et al., 2003b; Ellis et al., 1996; Lowell et al., 2019). Therefore, this results in Pietrain pigs having increased FFL (Edwards et al., 2003b; Lowell et al., 2019). Additionally, one study noted that LEA was increased by 3.0 cm^2 in Pietrain sired pigs (Edwards et al., 2003b). When considering carcass composition, this often consists of primal and subprimal weights in addition to carcass cutability calculations. In general, Pietrain pigs tend to have increased percent of chilled side weights for primals and subprimals (Edwards et al., 2003; Lowell et al., 2019; Morales et al., 2013), but Duroc pigs have increased primal and subprimal weights (Edwards et al, 2003; Morales et al., 2013). Additionally, one study reported Pietrain pigs have increased bone-in carcass cutting yield and bone-in lean cutting yield compared to Duroc pigs (Lowell et al., 2019). These results suggest that Pietrain-sired pigs have leaner carcasses with increased carcass cutting yields whereas Duroc-sired pigs hold an advantage in terms of primal and subprimal weights.

Pork Quality of Pietrain and Duroc-Sired Pigs

Although Pietrain-based sires undoubtedly increase lean meat yields, they are often not selected for meat quality characteristics. Previous literature has reported that Pietrain pigs may contain one copy of the mutated ryanodine receptor gene which is linked to “Porcine Stress Syndrome” or PSS (Barbut et al., 2008; Edwards et al., 2003a). The Porcine Stress Syndrome has detrimental effects on pork quality including PSE meat, which has been linked to the halothane gene. However, efforts have been made by both producers and packers in an attempt to reduce and eliminate PSE meat. From a producer standpoint, Pietrains utilized in modern day pork production are often tested for the halothane gene to ensure they are not used in commercial production (Barbut et al., 2008). Additionally, the packing industry has implemented branded pork programs which has led to decreased cases of PSE meat (Barbut et al., 2008). Unlike Pietrain pigs, Duroc-sired pigs are often selected for swine breeding programs that have intentions of improving overall meat quality (Edwards et al., 2003b; Lowell et al., 2019; NPPC, 1995).

In general, Duroc pigs have darker loins than Pietrain pigs (Edwards et al., 2003b) (Lowell et al., 2019), but the absolute difference between breeds varies between studies. Duroc-sired pigs have increased IMF content when compared to other swine breeds, but especially European breeds, which includes Pietrain pigs (Cilla et al., 2006; Damon et al., 2006; Lowell et al., 2019). Additionally, ultimate pH is increased in Duroc pigs suggesting an increased capacity to hold water when compared to Pietrain pigs (Edwards et al., 2003b; Lowell et al., 2019). In fact, older studies comparing Pietrain and Duroc pigs concluded Duroc pigs had superior WHC when compared to Pietrain pigs (Lonergan & Lonergan, 2005; Melody et al., 2004). But these studies may reflect the prevalence of PSE meat in older Pietrains. More recently, purge loss did not differ between Duroc and Pietrain-sired pigs (Lowell et al., 2018). In terms of instrumental tenderness of loin chops, results are also mixed with some reporting no differences between breeds (Edwards et al., 2003) and others a slight advantage in tenderness among Pietrain pigs (Lowell et al., 2019).

Comparisons of fresh ham quality of Duroc and Pietrain-sire pigs is nonexistent in the literature. Therefore, emphasizing the need for fresh ham quality research between these breeds. Additionally, fresh belly, cured belly, and bacon slice quality of Duroc and Pietrain-sired pigs is minimal in the literature. Again, this highlights the need for more research; specifically with bellies and bacon, as this is a profitable industry in the United Studies. However, one study evaluated belly and bacon characteristics amongst Duroc and Pietrain-sired pigs and barrows and gilts (Lowell et al., 2019). Not surprisingly, Duroc-sired pigs had thicker and firmer bellies as compared to Pietrain-sired pigs. Duroc-sired pigs also had a greater cooked yield percentage and bacon fat percentage; therefore, it is not surprising that Pietrain-sired pigs had leaner bacon slices. These results suggest that in addition to superior loin quality, Duroc-sired pigs also have superior belly quality characteristics.

CONCLUSION

Based on varying consumer preferences and export market demands, it is important to identify appropriate sire lines to fit these markets. Based on these varying preferences, deciding on a concrete definition for pork quality can be difficult as different countries hold different attributes of quality to higher standards. However, what remains the same is color, marbling, tenderness, juiciness, and flavor all influence pork quality and consumer purchasing decisions. Therefore, sire lines are extremely valuable for producers in order to achieve the traits they are selecting for in their designated markets. Currently, both Pietrain and Duroc terminal sire lines are used in the swine industry. Pietrain-based terminal sires are often selected to increase both carcass and lean yields whereas Duroc-based terminal sires improve meat quality, but also grow relatively quickly. Understanding the growth performance, carcass characteristics and composition, and pork quality of these breeds impact genetic companies, producers, packers, and the consumer. Therefore, the importance of understanding these characteristics is invaluable.

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CHAPTER 2: EFFECT OF PIETRAIN SIRE LINES ON EARLY AND AGED PORK QUALITY

ABSTRACT

Originally from Europe, Pietrain pigs have been incorporated into commercial swine production in the United States for many years as they are known for increasing feed efficiency, carcass yields, and lean meat yields. The objective of this study was to evaluate two separate Pietrain sire lines and their effects on growth performance, carcass characteristics, early and aged loin quality, early ham quality, and early belly quality. An American purebred terminal sire was chosen for feed efficiency and lean tissue accretion, which produced 135 pigs for the trial. A European crossbred (25% Pietrain) terminal sire was chosen for lean tissue accretion and produced 114 total pigs. The MIXED procedure of SAS was used to evaluate the fixed effects of sire line, sex, and the interaction between sire line and sex, and effects were considered significant at $P<0.05$. Overall (d0-91/98), average daily gain (**ADG**) tended to increase ($P=0.07$) in European barrows by 0.03 kg/d day compared to American sired pigs, but gain to feed (**G:F**) did not differ ($P=0.76$) between sire lines. European sired pigs had a greater ($P=0.04$) boneless carcass cutting yield (51.36 vs. 50.55%) as compared to American sired pigs. American sired pigs had darker loins as indicated by increased ($P<0.001$) early ventral visual color (3.72 vs. 3.26 units) and decreased ($P=0.05$) early ventral L* (51.10 vs. 51.99 units). Early chop visual color was increased ($P=0.03$) by 0.14 units and early chop L* was decreased ($P=0.03$) by 1.18 units indicating American sired pigs had darker colored chops. Both early ventral and chop visual marbling and ultimate pH did not differ between sire lines ($P\geq0.27$). American sired pigs had a greater ($P<0.001$) extractable lipid by 0.54% as compared to European sired pigs. American sired pigs had darker, heavier marbled, and firmer aged loins as ventral visual color, marbling, and firmness were increased ($P\leq0.02$) by 0.16, 0.39, and 0.19 units, respectively. Aged visual

chop marbling was increased ($P<0.001$) by 0.39 units in American sired pigs. Aged chop pH, instrumental tenderness, and cook loss did not differ ($P\geq0.20$) between sire lines. European sired pigs had thicker and firmer bellies as belly thickness and flop were increased ($P\leq0.01$) by 0.23 cm and 2.94 cm, respectively. Early ham visual color score (2.30 vs. 3.10 units) and instrumental L* (54.92 vs. 57.82 units) was decreased ($P<0.001$) for American sired pigs meaning they had darker hams. Ultimately, European sired pigs tended to have increased ADG and thicker bellies, but American sired pigs had improved loin quality and darker hams.

INTRODUCTION

Terminal sire selection is a crucial component of commercial swine production as terminal sires have the ability to influence growth performance, carcass characteristics, and meat quality traits. Although European swine producers have utilized Pietrain terminal sires longer than U.S. producers, Pietrain pigs are essential in modern day swine production in the United States (Edwards et al., 2003a). Pietrain pigs are known to increase feed efficiency and improve carcass and lean meat yields (Werner et al., 2010), but do not excel in terms of meat quality when compared to other terminal sires, especially Durocs (Gil et al., 2008). As Mexico is one of the largest importers of U.S. pork, the Pietrain pig is of high value such that Mexican consumers value lean product over products with improved pork quality (Edwards et al., 2003b; Lowell et al., 2018; Murphy et al., 2015). In addition to higher lean yields, Pietrain terminal sires also yield heavier muscled carcasses; however, as Pietrain terminal sires have been selected over time for specific traits, overall back fat and intramuscular fat content has decreased (Morales et al., 2013). This raises some concern as less back fat is associated with thinner bellies and poorer bacon processing characteristics. Within this study, two separate sire lines were used to evaluate pork quality parameters including loin, ham, and belly quality. The objective of this study was to compare those characteristics between an American purebred Pietrain sire line and a European crossbred Pietrain sire line. The American sire line was selected for maximum feed efficiency and lean tissue accretion while the European sire line was selected for carcass merit and lean tissue accretion.

MATERIALS AND METHODS

Protocols used during the live phase portion of the experiment were approved by the Institutional Animal Care and Use Committee at the University of Illinois.

Pig Background

Pigs (249 total) from 2 different sire lines of Pietrain ancestry (Choice Genetics, West Des Moines, IA) were used in the trial. An American, purebred Pietrain sire line selected for feed efficiency and lean tissue accretion provided 135 barrows and gilts. A European, 4-way proprietary crossbred (25% Pietrain) sire line selected for carcass merit and lean tissue accretion provided 114 barrows and gilts. Boars of both sire lines were mated to Camborough sows (Pig Improvement Company, Henderson, TN) and parity of the females was balanced between sire lines. All pigs were housed in pens (1.58 m^2/pig) of 3 pigs of the same sex and sire line. Floor space allowance was calculated using the equation ($A = k * BW^{0.667}$) in order to calculate a k-value (Gonyou et al., 2006). Each pen contained a feeder, nipple waterer, and a tri-bar slatted floor. Pigs were raised in blocks, approximately 2 weeks apart, based on farrowing group. Block 1 consisted of 69 pigs (36 barrows and 33 gilts) from the American Pietrain and 63 pigs (30 barrows and 33 gilts) from the European Pietrain. Block 2 consisted of 66 pigs (33 barrows and 33 gilts) from the American Pietrain and 51 pigs (24 barrows and 27 gilts) from the European Pietrain. A total of 44 pens were used in block 1 (11 barrow and 11 gilt pens from the American Pietrain, and 11 barrow and 11 gilt pens from the European Pietrain). A total of 39 pens were used in block 2 (11 barrow and 11 gilt pens from the American Pietrain, and 8 barrow and 9 gilt pens from the European Pietrain. Discrepancies in pen numbers were due to pig availability within each farrowing group.

A 3-phase, 91 d feeding program was used for block 1 and a 98 d feeding program was used for block 2. Day 0 of the experiment was the first day of the grower phase and beginning of the feeding portion of the trial. Pens of pigs were fed a grower diet from d 0 to d 35, an early finisher diet from d 36 to d 70, and a late finisher diet from d 71 through the end of the live phase (d 91 for block 1 and d 98 for block 2). All 3 diets were formulated to be iso-caloric and contained no ractopamine hydrochloride or dried distillers grains with or without solubles. Day 0 was considered the beginning of the feeding trial and pigs (10 weeks of age) were weighed to determine beginning weight. Pigs were also weighed at the end of each of the 3 feeding phases (d 35, 70, & 91 or 98). Daily feed allotments were recorded and data were summarized to calculate ADG, average daily feed intake (**ADFI**), and G:F. Day 91(block 1) and 98 (block 2) was considered the end of the feeding portion of the trial and all pigs were weighed in order to calculate overall ADG, ADFI, and G:F. At the end of the feeding trial, the heaviest pig from each pen (83 total pigs) was removed and transported to the University of Illinois Meat Science Laboratory (Urbana, IL) for slaughter. Two days later, the lightest pig from each pen (83 total pigs) was removed and transported to the University of Illinois Meat Science Laboratory for slaughter.

Federally Inspected Abattoir Slaughter and Carcass Characteristics

Pigs transported to the federally inspected abattoir (Rantoul, IL) were held in lairage for a minimum of 4 hours. Pigs were slaughtered under the supervision of the Food Safety and Inspection Service of the United States Department of Agriculture (USDA). Pigs were immobilized using carbon dioxide and then terminated via exsanguination. Carcasses were weighed approximately 45 minutes postmortem to determine hot carcass weight (**HCW**). Carcasses were chilled using the blast chill method for approximately 2 hours. Last rib fat was measured on the left side of each carcass in the determined location of the last rib. Standardized fat-free lean percentage was calculated using the equation (23.568 + 0.503 × (HCW, lb.) - 21.348 × (last rib back fat thickness, in.)) as described in procedure 2 for unribbed carcasses (Burson & Berg, 2001).

University of Illinois Meat Science Laboratory Slaughter and Carcass Characteristics

Pigs transported to the University of Illinois Meat Science Laboratory (Urbana, IL) were held in lairage for a minimum of 16 h prior to slaughter. Pigs were provided ad libitum access to water but had no access to feed during this time. Pigs were weighed immediately before slaughter to determine an ending live weight (**ELW**). Pigs were slaughtered under the supervision of the Food Safety and Inspection Service of the United States Department of Agriculture (USDA). Pigs were immobilized using head-to-heart electrical stunning and terminated via exsanguination. Carcasses were weighed approximately 45 min postmortem to determine HCW. Carcass yield was calculated by dividing the HCW by ELW and expressed as a percentage.

Carcasses were chilled at 4°C for a minimum of 20 h. Estimates of carcass composition were determined on the left side of each carcass, which was separated between the 10th and 11th rib to expose the longissimus thoracis (**LTL**). Tenth-rib back fat thickness was measured at ¾ the distance of the LTL from the dorsal process of the vertebral column. Loin eye area (**LEA**) was measured by tracing the surface of the LTL on acetate paper. The LTL tracings were measured in duplicate using a digitizer tablet (Wacom, Vancouver, WA) and Adobe Photoshop

CS6. The average of the two measurements was reported as LTL area. Standardized fat-free lean (**FFL**) percentage was calculated using the equation (8.588 + (0.465 × HCW, lb) – (21.896 × tenth rib fat thickness, in) + (3.005 × loin muscle area, in2)) / HCW, lb) × 100 as described in procedure 1 for ribbed carcasses (Burson & Berg, 2001).

Carcass Fabrication

Carcass fabrication followed the same method outlined by Boler et al. (2001). At 1d postmortem, the left side of each chilled carcass was weighed and then fabricated into a pork leg (NAMP #401), skin-on whole loin, pork shoulder (NAMP #403), neck bones (NAMP #421), jowl (NAMP #419), skin-on natural fall belly (NAMP #408), and spareribs (NAMP #416) to meet the specifications as described in the North American Meat Institute Meat Buyer's Guide (NAMI, 2014). Each primal piece was weighed before further fabrication. Legs were skinned and trimmed of fat to meet the specifications of a NAMP #402 trimmed ham. Further fabrication of the hams followed the method outlined by Boler et al. (2012). The loin was separated into an anterior and posterior portion, due to the separation at the location of the 10^{th} and 11^{th} rib to assess carcass composition. The anterior and posterior portions of the loin were skinned and trimmed of fat to meet the specifications of a NAMP #410 bone-in loin. Both halves of the trimmed, bone-in loin were weighed, as a set, to determine the weight of the whole skinless bone-in loin. Both the anterior and posterior portions were then fabricated, and weighed as a set, to meet the specifications of a NAMP #414 Canadian back loin, a NAMP #415A tenderloin, and a NAMP #413D sirloin. The whole shoulder was skinned and trimmed of fat to meet the specifications of a skinned pork shoulder (NAMP #404). The Boston butt was separated from the picnic to form a NAMP #406 bone-in Boston butt and a NAMP #405 bone-in picnic, and then weighed individually. The bones were removed from each piece to meet the specifications of a

NAMP #406A boneless Boston butt and a NAMP #405A boneless picnic with the triceps brachii (shoulder cushion) attached. Carcass cutability was expressed as a percentage of chilled left side weight to account for variability in body weight (**BW**) and HCW. The following equations were used to calculate cutability:

Bone-in lean cutting yield, % = [(trimmed ham (NAMP #402), kg + bone-in trimmed Boston butt (NAMP #406), kg + bone-in picnic (NAMP #405), kg + trimmed loin (NAMP #410), kg) / chilled left side weight, kg]×100

Bone-in carcass cutting yield, % = [(bone-in lean cutting yield components + natural fall belly (NAMP #408), kg) / chilled left side weight, kg] × 100

Boneless carcass cutting yield, % = [(inside ham (NAMP #402F), kg + outside ham (NAMP #402E), kg + knuckle (NAMP #402H), kg) + inner shank, kg + lite butt, kg + Canadian back (NAMP #414), kg +tenderloin (NAMP #415A), kg + sirloin (NAMP #413D), kg) + boneless Boston butt (NAMP #406A), kg + boneless picnic (NAMP #405A), kg + natural fall belly (NAMP #408), kg)) / chilled left side weight] × 100

Natural fall bellies, the semimembranosus muscle (**SM**), and Canadian back loins were collected to assess fresh belly quality, fresh ham quality, and fresh and aged loin quality.

Early Postmortem Loin Quality Evaluation

At 1 d postmortem, quality measurements for instrumental color, visual color, visual marbling, subjective firmness, and ultimate pH were conducted by trained University of Illinois personnel following the procedure outlined by Lowell et al. (2017). Loins were re-faced and evaluated for quality parameters on the cut surface of the LTL posterior to the 10th rib. Oxygenation of myoglobin occurred at 4°C for approximately 20 minutes before quality measurements were evaluated. Instrumental L*(lightness), a* (redness), and b* (yellowness; CIE

1978) were measured with a Minolta CR-400 Chroma meter (Minolta Camera Co., Ltd., Osaka, Japan) using a D65 light source, 2° observer angle, an 8 mm aperture, and calibrated using a white tile. Instrumental L* does not change within 30 min of oxygen exposure and instrumental a* values do not change after 10 min of oxygen exposure (Brewer et al., 2001). Therefore, 20 min was sufficient to allow for appropriate oxygenation of myoglobin. Ultimate pH was measured on the ventral side of the LTL muscle in the approximate location of the 10th rib using a Reed data logger, calibrated at 4°C, fitted with a Hanna glass electrode (REED SD-230 Series pH/ORP Datalogger, 0.00 to 14.00 pH/0-199 mV; Hanna FC200B electrode). Visual color and marbling scores (NPPC, 1999), and subjective firmness scores (NPPC, 1991) were determined by a single technician. After 1d postmortem quality measures were complete, loins were vacuum packaged and aged for 13 d at 4°C.

Early Postmortem Ham Quality Evaluation

Ham quality was evaluated on the medial side of the SM on day 1 postmortem. Quality evaluations included instrumental color, visual color, and ultimate pH. Instrumental color (L*, a*, and b*) was measured with a Minolta CR-400 Chroma meter (Minolta Camera Co., Ltd., Osaka, Japan) using a D65 light source, open aperture, 2° observer angle, and 8 mm opening; calibrated with a white tile. Visual color was assessed by a single trained individual using a color scale range of 1 to 4 (1 being visually the darkest and 4 being visually the lightest). A Reed data logger was calibrated at 4°C, using a Hanna glass electrode (REED SD-230 Series pH/ORP Datalogger, 0.00 to 14.00 pH/0 to 199 mV; Hanna FC200B electrode) and used to measure ultimate pH of each SM.

Early Postmortem Belly Quality

Block 1 bellies were evaluated on day 3 postmortem and block 2 bellies were evaluated on day 1 postmortem. A sharpened back fat probe was used to measure belly thickness at 3 locations throughout the belly. At 50 percent of the width of the belly, thickness measurements were collected at 25%, 50%, and 75% of the belly length, anterior to posterior. Those 3 measurements were averaged to determine belly thickness. Bellies were placed skin side down, over a stationary metal bar, and the distance between the inside edges were measured to obtain a belly flop distance.

Aged Postmortem Loin Quality Evaluation

Aged postmortem quality loin evaluation followed that outlined by Lowell et al. (2017). At 14 d postmortem, loins were removed from the packaging, allowed to drip for approximately 20 minutes, and weighed. Purge loss (%) was calculated using the following equation:

Purge Loss, % = [(1 d weight, kg – 14 d weight, kg) / 1 d weight, kg] ×100

Loins were exposed to oxygen for at least 20 min and then quality measurements for instrumental color, visual color, visual marbling, subjective firmness, and aged ultimate pH were conducted on the ventral surface of the loins, using the same procedures as the 1 d postmortem quality evaluations. Ambient room temperature during evaluations was approximately 4°C. After quality evaluations were completed on the ventral surface of the loins, three loin chops from each loin were removed, posterior to the cut at the 10^{th} rib, for evaluation of proximate composition (moisture and extractable lipid), cook loss, and Warner-Bratzler shear force (**WBSF**). Chops were sliced into 2.54 cm thick chops using a Bizerba deli slicer SE 12 D US (Bizerba USA Inc. Piscataway, NJ). Chop 1 was exposed to oxygen for at least 20 minutes before evaluation. Then, instrumental color, visual color and marbling, and subjective firmness were measured in the same manner as described above. Chop 1 was then trimmed free of all subcutaneous fat and secondary muscles, packaged in Whirl-Pak bags (Nasco, Ft. Atkinson, WI), and stored at -2°C until determination of moisture and extractable lipid. Chop 2 was vacuum packaged and stored at -2°C until determination cook loss (%) and WBSF. Chop 3 was vacuum packaged and stored at -2°C as a backup sample.

Cook Loss and Warner-Bratzler Shear Force

The 2.54 cm thick chops were removed from the freezer at least 24 h prior to analysis and allowed to thaw thoroughly at approximately 1°C. Analyses followed those outlined by Richardson et al. (2018). Chops were individually weighed and then cooked on a Farberware Open Hearth grill (model 455N, Walter Kidde, Bronx, NY, USA). Chops were cooked, on one side, to an internal temperature of 31.5°C, flipped, and then cooked until they reached an internal temperature of 63°C, at which point they were removed. Internal temperature, during cooking, was monitored using copper-constantan thermocouples (Type T, Omega Engineering, Stamford, CT, USA) placed in the approximate geometric center of each chop and connected to a digital scanning thermometer (model 92000-00, Barnat Co, Barrington, IL). Chops were allowed to cool to approximately 25°C, and weighed again to determine percent cook loss. Five 1.25 cm diameter cores were removed parallel to the orientation of the muscle fibers and sheared using a Texture Analyzer TA.HD Plus (Texture Technologies Corp., Scarsdale, NY/Stable Mirosystems, Godalming, UK) with a blade speed of 3.33 mm/s and a load cell capacity of 100 kg. The shear force value for the 5 cores were averaged and the average was reported as WBSF.

Loin Proximate Composition

Individual, trimmed loin chops were packaged in Whirl-Pak bags (Nasco, Ft. Atkinson, WI) and stored at -2°C until analysis. Loin chops were thawed at 25°C and then homogenized in a Cuisinart (East Windsor, NJ) food processor. Duplicate 10 g samples from each loin chop were placed in a drying oven set at 110°C for at least 24 h. Moisture and extractable lipid content were determined using the chloroform-methanol solvent method described by Novakofski et al. (1989).

Statistical Analysis

Data were analyzed using the MIXED procedure of SAS (SAS Inst. In., Cary, NC) as a 2 × 2 factorial arrangement (sire line × sex) of treatments in a randomized complete block design. Pen (83 total) served as the experimental unit for all fixed variables. Fixed effects were sire line, sex, and the interaction between sire line and sex. Block (*n*=2) served as random variable. Effect of sire line, sex, and the interaction between sire line and sex was considered significant at $P<0.05$. Least squares means were separated using a probability of difference (PDIFF) statement in the MIXED procedure of SAS. Normality of residuals was tested using the UNIVARIATE procedure of SAS. Homogeneity of variances was tested using the Levene's hovtest option in the GLM procedure of SAS.

RESULTS

Growth Performance, Carcass Characteristics, and Cutability

Birth weight did not differ between sire lines ($P=0.40$), but weaning weight increased ($P<0.01$) by 0.45 kg in European pigs compared with American pigs (Table 2.1). During the initial feeding phase (d0-35), ADG, ADFI, and G:F did not differ between sire lines ($P\geq0.34$). In phase 2 (d36-70) and 3 (d71-91/98), ADG, and G:F did not differ ($P\geq0.16$) between sire lines, but ADFI was 3-4% greater in European-sired pigs compared with American sired pigs. During phase 3 American-sired pigs had an increased (0.0463 vs. 0.0458; $P=0.01$) k-value compared to European pigs. Overall (d0-d91/98) ADG, ADFI, and G:F did not differ ($P\geq0.06$) between sire lines.

On carcass data collected from the heaviest and lightest pig in each pen, ELW, HCW, and carcass yield did not differ (*P*≥0.10) between sire lines (Table 2.2). European sired pigs had increased (*P*<0.001) LEA by 5.19 cm^2 and FFL by 1.63% units. American sired pigs had more tenth rib back fat (1.98 vs. 1.82 cm; *P*=0.03) in comparison to European sired pigs. On carcass data collected from the second heaviest pig in each pen, HCW was increased in (*P*=0.02) by 2.48 kg in European sired pigs. Last rib back fat and FFL did not differ (*P*≥0.33) between sire lines.

The cutability of each primal and of the carcass overall are displayed in tables 2.3 (shoulder), 2.4 (loin), 2.5 (ham), 2.6 (belly and other cuts), and 2.7 (overall). European sired pigs had heavier whole shoulders (13.22 vs. 12.88 kg; *P*=0.03), bone-in Boston butts (4.23 vs. 4.10 kg; *P*=0.02), bone-in picnics (5.59 vs. 5.37 kg; *P*<0.01), and boneless Boston butts (3.94 vs. 3.82 kg; *P*=0.04). Additionally, European sired pigs had heavier boneless picnics (4.10 vs. 3.89 kg; *P*<0.01) and boneless shoulders (8.04 vs. 7.71 kg; *P*=0.04). European sired pigs had increased percent of chilled side weight for boneless picnics (*P*=0.01) by 0.25% and boneless shoulders by 0.33%. American sired pigs had an increased (*P*=0.02) percent of chilled side weight for jowls by 0.11% compared to European sired pigs.

European sired pigs had heavier trimmed loins (11.34 vs. 11.00 kg; *P*=0.03), Canadian backs (3.87 vs. 3.62 kg; *P*<0.001), tenderloins (0.46 vs. 0.44 kg; *P*=0.03), and boneless loins (5.22 vs. 4.92 kg; *P*<0.001). European sired pigs had increased (*P*<0.001) percent of chilled side weight for Canadian backs by 0.36% and boneless loins by 0.38%, compared to American sired pigs. Weights for whole loin, sirloin, backribs, and backbone did not differ between sire lines (*P*≥0.08).

European sired pigs had heavier whole hams (12.17 vs. 11.82 kg; *P*=0.01), trimmed hams (10.10 vs. 9.82 kg; *P*=0.02), inside hams (1.91 vs. 1.83 kg; *P*<0.01), outside hams (1.91 vs. 1.83

kg; $P<0.01$), and boneless hams (6.04 vs. 5.82 kg; $P=0.01$). European sired pigs had increased percent of chilled side weight for outside hams ($P=0.04$) by 0.15% compared to American sired pigs. Knuckle, inner shank, and lite butt weights did not differ between sire lines ($P \geq 0.44$).

Natural fall belly and sparerib weight did not differ between sire lines ($P \geq 0.57$); neither did percent of chilled side weight for either of these pieces ($P \geq 0.10$). Standardized trim weight, leaf fat weight, feet weight, and percent of chilled side weight for all 3 pieces did not differ between sire lines ($P \geq 0.08$).

Bone-in carcass cutting yield and bone-in lean cutting yield did not differ between sire lines ($P \geq 0.13$). When compared to American pigs, European gilts had an increased ($P=0.05$) bone-in carcass cutting yield by approximately 1.65% as indicated by a sire line by sex interaction. European sired pigs had increased ($P=0.04$) boneless carcass cutting yields by 0.81% as compared to American sired pigs.

Pork Quality

American sired pigs had an increased ($P<0.001$) early ventral visual color score by 0.46 units and ventral subjective firmness by 0.32 units (Table 2.8). European sired pigs had an increased ($P=0.05$) early ventral L* by 0.89 units compared to American pigs. Early ventral marbling, a*, and b* did not differ ($P \geq 0.23$) between sire lines. American sired pigs had increased ($P=0.03$) early chop visual color score by 0.14 units and increased ($P<0.001$) extractable lipid ($P<0.001$) by 0.54% compared to European pigs. American barrows, American gilts, and European gilts had an increased ($P=0.03$) early chop visual color score compared to European barrows indicated by a sire line by sex interaction. European pigs had an increased ($P=0.03$) early chop L* by 1.18 units compared to American pigs. Early chop visual marbling, subjective firmness, a*, b*, pH, and moisture percent did not differ ($P \geq 0.07$) between sire lines.

American sired pigs had increased (P≤0.02) aged ventral visual color (3.53 vs. 3.37 units), visual marbling (2.43 vs. 2.04 units), and subjective firmness (3.61 vs. 3.42 units; Table 2.9). Aged ventral L*, a*, b*, and purge loss did not differ (P≥0.21) between sire lines. Aged chop visual marbling was increased (P<0.001) by 0.39 units in American sired pigs as compared to European sired pigs. Aged chop visual color score, subjective firmness, L*, a*, b*, chop pH, WBSF, and cook loss did not differ (P≥0.09) between sire lines. However, there was a sire line by sex interaction (P=0.04) for WBSF. Within the American sired pigs, barrows were more tender than gilts, but within the European sired pigs, gilts were more tender than barrows thus, driving the sire line by sex interaction.

Belly thickness was increased (P<0.001) by 0.23 cm and belly flop was increased (P<0.01) by 2.94 cm in European sired pigs (Table 2.10). European sired pigs had increased (P<0.01) visual ham color by 0.80 units, ham L* by 2.9 units, and b* by 1.0 units compared to American sired pigs. Early ham a* and ham pH did not differ (P≥0.08) between sire lines.

DISCUSSION

In general, Europe has utilized the Pietrain pig much longer than U.S. swine producers (Edwards et al., 2003a); however, they are being incorporated into modern day swine production as they have increased feed efficiency and improve both carcass and lean meat yields. However, it is recognized that selecting Pietrain sires can be at the expense of pork quality characteristics when compared to other sire lines (Kušec et al., n.d.). Therefore, Pietrain terminal sires are often utilized in export markets where pork is purchased on a volume basis and consumer preference includes leaner pork cuts (Lowell et al., 2018). Therefore, the objective of this study was to evaluate the effects of an American purebred Pietrain sire, intended for feed efficiency and lean tissue accretion, and a European crossbred Pietrain sire, intended for carcass merit and lean tissue accretion, and their effect on early and aged pork quality.

European sired pigs were heavier at weaning, but ADG and G:F did not differ between the two sire lines. In the present study, *k* value was measured to determine the effect of floor space allowance on overall pig performance, whereas *k* represents the space allowance coefficient. American sired pigs had an increased *k* value indicating they had more space allowance in order to grow (Gonyou et al., 2006). Additionally, there were no differences in ELW, HCW, or carcass yield. However, European sired pigs had leaner carcasses, specifically at the 10^{th} rib, with larger loin eyes, which ultimately led to an increase in FFL. Although bone-in carcass cutting yield and bone-in lean cutting yield did not differ between the two sire lines, European sired pigs had an increase in boneless carcass cutting yield. Overall, neither sire line was superior in regards to growth performance, but European sired pigs did have improved carcass merit. European sired pigs had a greater FFL by approximately 1.50% units, which is driven by an increase in LEA as there were no differences in HCW or back fat.

In terms of loin quality, American sired pigs had slightly darker and firmer loins at both early and aged time points as well as slightly heavier marbled aged loins. At 1 d postmortem, American sired pigs had slightly darker chops with a greater amount of extractable lipid. Additionally, American sired pigs had heavier marbled aged chops. However, there were no differences amongst the two sire lines in regards to early and aged ultimate pH, purge loss, instrumental tenderness, or cook loss. Furthermore, European sired pigs had thicker and firmer bellies, while American sired pigs had darker and slightly less yellow colored hams. Thus, overall, American sired pigs exceled in both loin and ham quality whereas European sired pigs held the advantage in overall belly quality. While statistically differently, the scope of difference in loin quality characteristics was comparatively small.

CONCLUSION

Pietrain terminal sires are often utilized in swine production as they are feed efficient and increase both carcass and lean meat yields. The objective of this study was to compare an American purebred Pietrain sire, selected for feed efficiency and lean tissue accretion, and a European crossbred Pietrain sire, selected for carcass merit and lean tissue accretion, and their effect on early and aged pork quality. Overall, there were no differences in growth performance, but European sired pigs were leaner and had improved carcass merit. Additionally, American sired pigs exhibited improved loin and ham quality characteristics whereas European sired pigs had thicker and firmer bellies. Therefore, for producers and packers that value lean meat yield, the European Pietrain sire line is the superior choice. On the contrary, when loin quality is at a premium, the American Pietrain sire line is the preferred choice.

FIGURES

Figure 2.1. The effects of sire line and sex on instrumental tenderness using the Warner-Bratzler shear force (kg) method of aged pork loins.

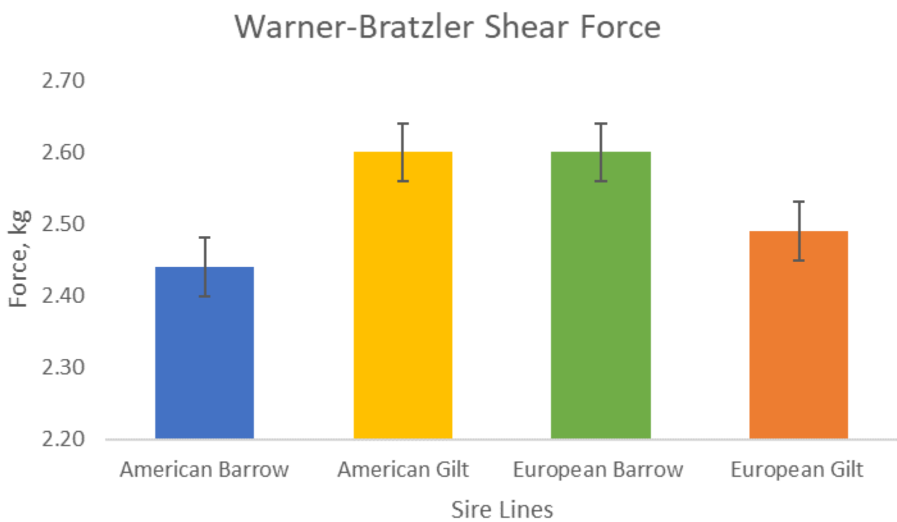
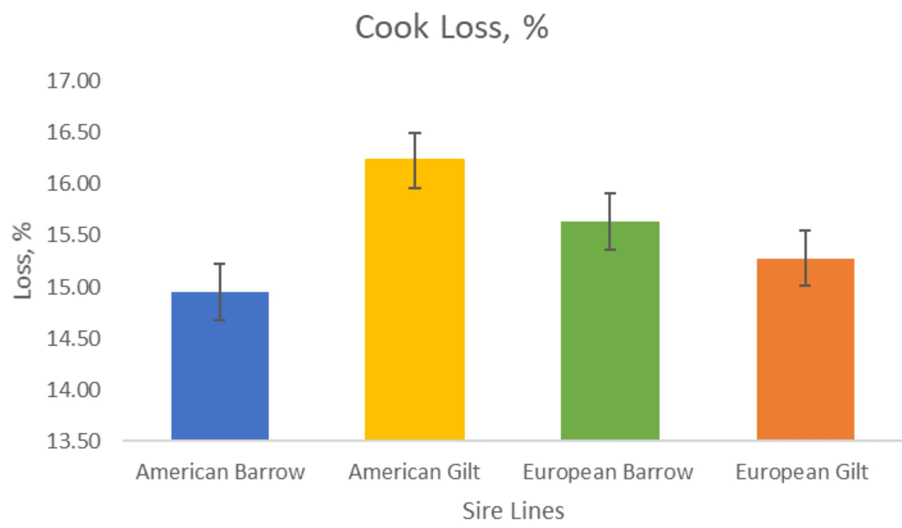


Figure 2.2. The effects of sire line and sex on cook loss (%) of aged pork loins.



TABLES

Table 2.1. Main effects of sire line and sex on growth characteristics

	Sire line		Sex			*P*-values		
Item	American	European	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	44	39	41	42				
Birth wt, kg	1.60	1.63	1.65	1.58	0.03	0.40	0.04	0.39
Weaning wt, kg	6.63	7.08	6.89	6.82	0.32	< 0.01	0.63	0.32
Phase 1 (d0-35)[1]								
BW d0, kg	30.71	30.71	30.94	30.48	0.37	0.98	0.07	0.18
ADG, kg/d	0.94	0.95	1.01	0.88	0.04	0.51	< 0.001	0.95
ADFI, kg/d	2.07	2.05	2.20	1.92	0.06	0.34	< 0.001	0.87
G:F	0.45	0.45	0.45	0.45	0.01	0.46	0.70	0.75
BW d35, kg	63.65	63.65	66.27	61.02	1.86	1.00	< 0.001	0.54
Phase 2 (d36-70)								
ADG, kg/d	1.18	1.21	1.26	1.12	0.02	0.16	< 0.001	0.13
ADFI, kg/d	3.15	3.28	3.47	2.96	0.04	< 0.01	< 0.001	0.88
G:F	0.37	0.37	0.36	0.38	0.01	0.71	0.02	0.30
BW d70, kg	104.34	106.13	110.00	100.48	2.04	0.06	< 0.001	0.22
Phase 3 (d71-91/98)[2]								
ADG, kg/d	1.03	1.04	1.06	1.01	0.08	0.63	0.12	0.48
ADFI, kg/d	3.34	3.44	3.58	3.20	0.09	0.05	< 0.001	0.92
G:F	0.31	0.30	0.30	0.31	0.02	0.59	0.01	0.42
BW d91 & d98	129.17	131.40	135.59	124.99	3.74	0.08	< 0.001	0.52
k-value d91/98	0.0463	0.0458	0.0448	0.0474	< 0.001	0.01	< 0.001	0.49
Overall (d0-91/98)								
ADG, kg/d	1.04	1.07	1.11	1.00	0.01	0.07	< 0.001	0.87
ADFI, kg/d	2.79	2.85	3.01	2.63	0.02	0.06	< 0.001	0.78
G:F	0.37	0.37	0.36	0.38	< 0.01	0.76	< 0.001	0.43

[1]Pigs were approximately 10 wks old on d0.

[2]Block 1 was harvested on day 91. Block 2 was harvested on day 98.

Table 2.2. Main effects of sire line and sex on carcass characteristics.[1]

Item	Sire Line		Sex			*P*-values		
	American	European	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	44	39	41	42				
University of Illinois[1]								
Ending live weight, kg	129.22	128.66	134.28	123.60	5.44	0.81	< 0.001	0.38
HCW, kg[2]	100.12	102.01	105.08	97.05	3.19	0.10	< 0.001	0.81
Carcass yield, %	78.38	79.28	78.84	78.82	0.63	0.27	0.98	0.36
Loin muscle area, cm^2	46.73	51.92	49.25	49.40	2.48	< 0.001	0.87	0.45
10th rib back fat depth, cm	1.98	1.82	2.15	1.65	0.14	0.03	< 0.001	0.77
Standardized fat-free lean, %[3]	52.66	54.29	52.22	54.73	1.23	< 0.001	< 0.001	0.77
Federally Inspected Abattoir[4]								
HCW, kg	97.28	99.76	102.66	94.38	3.31	0.02	< 0.001	0.62
Last rib back fat depth, cm	3.39	3.53	3.89	3.03	0.11	0.33	< 0.001	0.18
Standardized fat-free lean, %[5]	48.07	47.61	46.23	49.45	0.47	0.45	< 0.001	0.18

[1]Values are based on data collected from the heaviest and lightest pig in each pen.

[2]HCW includes the left and right sides with leaf fat and standardized trim still intact.

[3]Standardized fat-free lean = ((8.588 + (0.465 x HCW, lb) - (21.896 x fat depth, in) + (3.005 x LTL area, in^2)) ÷ HCW) x 100, (Burson and Berg, 2001).

[4]Values are based on data collected from the second heaviest pig in each pen.

[5]Standardized fat-free lean = ((23.568 + (0.503 x HCW, lb) - (21.348 x fat thickness, in))÷HCW) x 100, (Burson and Berg, 2001).

Table 2.3. Main effects of sire line and sex on shoulder carcass cuts.

	Sire Line		Sex			*P*-values		
Item	American	European	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	44	39	41	42				
Whole shoulder, kg	12.88	13.22	13.59	12.51	0.40	0.03	< 0.001	0.73
% chilled side wt	25.53	25.69	25.54	25.68	0.71	0.42	0.50	0.69
Bone-in Boston, kg	4.10	4.23	4.32	4.01	0.15	0.02	< 0.001	0.69
% chilled side wt	8.12	8.22	8.12	8.22	0.25	0.25	0.28	0.75
Bone-in picnic, kg	5.37	5.59	5.68	5.28	0.14	< 0.01	< 0.001	0.97
% chilled side wt	10.66	10.86	10.68	10.84	0.23	0.06	0.12	0.78
Boneless Boston, kg	3.82	3.94	4.02	3.74	0.14	0.04	< 0.001	0.45
% chilled side wt	7.57	7.67	7.56	7.68	0.24	0.36	0.26	0.48
Boneless picnic, kg	3.89	4.10	4.14	3.85	0.05	< 0.01	< 0.001	0.88
% chilled side wt	7.71	7.96	7.76	7.91	0.07	0.01	0.08	0.91
Neckbones, kg	1.10	1.11	1.22	1.09	0.08	0.60	0.18	0.40
% chilled side wt	2.18	2.17	2.11	2.24	0.16	0.81	0.01	0.51
Jowl, kg	1.57	1.55	1.67	1.45	0.07	0.39	< 0.001	0.44
% chilled side wt	3.11	3.00	3.14	2.97	0.13	0.02	< 0.001	0.28
Clear plate, kg	0.75	0.77	0.79	0.73	0.04	0.59	0.17	0.17
% chilled side wt	1.48	1.50	1.48	1.50	0.07	0.79	0.86	0.18
Boneless shoulder, kg[1]	7.71	8.04	0.18	0.18	0.18	< 0.01	< 0.001	0.72
% chilled side wt	15.28	15.61	15.30	15.59	0.31	0.04	0.07	0.52

[1]Boneless shoulder = boneless Boston butt (NAMP # 406A), kg + boneless picnic (NAMP #405A), kg.

Table 2.4. Main effects of sire line and sex on loin carcass cuts.

	Sire Line		Sex			*P*-values		
Item	American	European	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	44	39	41	42				
Whole loin, kg	13.36	13.73	14.19	12.90	0.41	0.08	< 0.001	0.69
% chilled side wt	26.41	26.55	26.62	26.34	0.72	0.53	0.22	0.52
Trimmed loin, kg	11.00	11.34	11.45	10.89	0.20	0.03	< 0.001	0.38
% chilled side wt	21.79	22.00	21.51	22.28	0.29	0.24	< 0.001	0.19
Canadian Back, kg	3.62	3.87	3.77	3.72	0.05	< 0.001	0.43	0.46
% chilled side wt	7.16	7.52	7.07	7.62	0.08	< 0.001	< 0.001	0.35
Tenderloin, kg	0.44	0.46	0.46	0.45	0.01	0.03	0.17	0.48
% chilled side wt	0.88	0.89	0.86	0.91	0.01	0.34	< 0.01	0.34
Sirloin, kg	0.86	0.88	0.88	0.86	0.03	0.09	0.12	0.06
% chilled side wt	1.70	1.72	1.66	1.76	0.04	0.50	< 0.001	0.07
Backribs, kg	0.91	0.89	0.92	0.88	0.05	0.36	0.04	0.50
% chilled side wt	1.80	1.72	1.73	1.80	0.09	0.09	0.11	0.42
Backbone, kg	2.16	2.20	2.23	2.14	0.10	0.34	0.03	0.57
% chilled side wt	4.28	4.28	4.20	4.36	0.18	0.96	0.02	0.60
Boneless loin, kg[1]	4.92	5.22	5.11	5.02	0.07	< 0.001	0.21	0.32
% chilled side wt	9.75	10.13	9.60	10.29	0.11	< 0.001	< 0.001	0.25

[1]Boneless loin = Canadian back loin (NAMP #414), kg + tenderloin (NAMP #415A), kg + sirloin (NAMP #413D), kg.

Table 2.5. Main effects of sire line and sex on ham carcass cuts.

	Sire Line		Sex			*P*-values		
Item	American	European	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	44	39	41	42				
Whole ham, kg	11.82	12.17	12.26	11.73	0.32	0.01	< 0.001	0.24
% chilled side wt	23.44	23.70	23.07	24.06	0.53	0.21	< 0.001	0.12
Trimmed ham, kg	9.82	10.10	10.12	9.80	0.15	0.02	0.01	0.11
% chilled side wt	19.51	19.71	19.07	20.14	0.21	0.34	< 0.001	0.06
Inside ham, kg	1.83	1.91	1.89	1.85	0.04	< 0.01	0.25	0.77
% chilled side wt	3.63	3.73	3.55	3.80	0.75	0.06	< 0.001	0.73
Outside ham, kg	2.56	2.69	2.64	2.61	0.08	< 0.01	0.49	0.23
% chilled side wt	5.09	5.24	4.97	5.36	0.13	0.04	< 0.001	0.23
Knuckle, kg	1.43	1.44	1.45	1.42	0.03	0.68	0.19	0.57
% chilled side wt	2.84	2.80	2.73	2.92	0.05	0.35	< 0.001	0.58
Inner shank, kg	0.72	0.67	0.74	0.65	0.05	0.46	0.16	0.25
% chilled side wt	1.41	1.30	1.38	1.32	0.09	0.38	0.62	0.23
Lite butt, kg	0.30	0.29	0.29	0.30	0.03	0.44	0.29	0.16
% chilled side wt	0.60	0.58	0.55	0.63	0.06	0.25	< 0.001	0.17
Boneless ham, kg[1]	5.82	6.04	5.97	5.88	0.15	0.01	0.27	0.39
% chilled side wt	11.56	11.78	11.25	12.08	0.25	0.14	< 0.001	0.38

[1]Boneless ham = inside ham (NAMP #402F), kg + outside ham (NAMP #402E), kg + knuckle (NAMP #402H), kg.

Table 2.6. Main effects of sire line and sex on belly and miscellaneous cuts.

	Sire Line		Sex			*P*-values		
Item	American	European	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	44	39	41	42				
Natural fall belly, kg	7.06	7.13	7.43	6.76	0.30	0.57	< 0.001	0.46
% chilled side wt	13.96	13.79	13.94	13.81	0.52	0.30	0.44	0.37
Spareribs, kg	1.73	1.73	1.76	1.70	0.71	0.97	0.01	0.23
% chilled side wt	3.43	3.37	3.31	3.49	0.13	0.10	< 0.001	0.26
Miscellaneous Cuts								
Standardized trim, kg	0.16	0.15	0.18	0.14	0.03	0.55	0.01	0.80
% chilled side wt	0.32	0.29	0.33	0.28	0.06	0.39	0.05	0.87
Leaf fat, kg	0.77	0.83	0.92	0.68	0.04	0.08	< 0.001	0.06
% chilled side wt	1.52	1.59	1.72	1.39	0.08	0.22	< 0.001	0.08
Front and back foot, kg	1.22	1.11	1.15	1.19	0.12	0.30	0.73	0.39
% chilled side wt	2.45	2.16	2.16	2.45	0.23	0.22	0.23	0.36

Table 2.7. Main effects of sire line and sex on carcass cutability.

	Sire Line		Sex			*P*-values		
Item	American	European	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	44	39	41	42				
Bone-in carcass cutting yield, %[1]	74.00	74.59	73.41	75.18	1.45	0.26	< 0.01	0.05
Bone-in lean cutting yield, %[2]	60.79	59.45	59.45	61.40	0.95	0.13	< 0.001	0.07
Boneless carcass cutting yield, %[3]	50.55	51.36	50.13	51.77	1.14	0.04	< 0.001	0.23

[1]Bone-in carcass cutting yield = [(trimmed ham, kg + bone-in Boston, kg + bone-in picnic, kg + trimmed loin, kg + natural fall belly, kg) ÷ left side chilled weight, kg] x 100.

[2]Bone-in lean cutting yield = [(trimmed ham, kg + bone-in Boston, kg + bone-in picnic, kg + trimmed loin, kg) ÷ left side chilled weight, kg] x 100.

[3]Boneless carcass cutting yield = [(inside ham, kg + outside ham, kg + knuckle, kg) + (Canadian back loin, kg + tenderloin, kg + sirloin, kg)+ (boneless Boston, kg + boneless picnic, kg) + (belly, kg)) ÷ left side chilled weight] x 100.

Table 2.8. Main effects of sire line and sex on early loin and chop face quality and color[1]

	Sire Line		Sex			*P*-values		
Item	American	European	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	44	39	41	42				
Loin								
Visual color[2]	3.72	3.26	3.50	3.48	0.06	< 0.001	0.73	0.32
Visual marbling[3]	1.92	1.84	1.94	1.82	0.11	0.27	0.09	0.61
Subjective firmness[4]	3.72	3.40	3.56	3.55	0.06	< 0.001	0.89	0.69
Lightness, L*[5]	51.10	51.99	51.56	51.53	0.50	0.05	0.95	0.70
Redness, a*[6]	9.84	10.14	9.93	10.04	0.19	0.23	0.67	0.39
Yellowness, b*[7]	7.97	8.27	8.11	8.13	0.20	0.23	0.93	0.90
Chop								
Visual color	3.48	3.34	3.36	3.45	0.07	0.03	0.17	0.03
Visual marbling	2.22	2.13	2.26	2.09	0.07	0.34	0.07	0.24
Subjective firmness	3.24	3.35	3.26	3.33	0.08	0.23	0.45	0.32
Lightness, L*	54.65	55.83	55.69	54.79	1.62	0.03	0.09	0.98
Redness, a*	8.82	9.04	8.99	8.86	0.45	0.41	0.62	0.84
Yellowness, b*	7.31	7.65	7.60	7.36	0.60	0.19	0.35	0.90
Chop pH	5.69	5.68	5.69	5.68	0.05	0.63	0.21	0.69
Moisture, %	73.49	73.59	73.28	73.79	0.15	0.33	< 0.001	0.46
Extractable Lipid, %	2.53	1.99	2.52	2.00	0.08	< 0.001	< 0.001	0.47

[1]Early postmortem traits were evaluated 1 d postmortem

[2]NPPC color based on the 1999 standards measured in half point increments where 1 = palest, 6 = darkest.

[3]NPPC marbling based on the 1999 standards measured in half point increments where 1 = least amount of marbling, 6 = greatest amount of marbling.

[4]NPPC firmness based on the 1991 scale measured in half point increments where 1 = softest, 5 = firmest.

[5]L* measures darkness (0) to lightness (100; greater L* indicates a lighter color).

[6]a* measures redness (greater a* indicates a redder color).

[7]b* measures yellowness (greater b* indicates a more yellow color).

Table 2.9. Main effects of sire line and sex on aged loin and chop quality[1]

Item	Sire Line		Sex		SEM	*P*-values		
	American	European	Barrows	Gilts		Sire Line	Sex	Sire line × Sex
Pens, n	44	39	41	42				
Loin								
Visual color[2]	3.53	3.37	3.44	3.47	0.06	0.01	0.66	0.23
Visual marbling[3]	2.43	2.04	2.38	2.09	0.06	< 0.001	< 0.001	0.06
Subjective firmness[4]	3.61	3.42	3.53	3.51	0.06	0.02	0.76	0.76
Lightness, L*[5]	54.47	54.63	54.64	54.46	1.04	0.75	0.72	0.83
Redness, a*[6]	9.44	9.34	9.43	9.35	0.16	0.63	0.73	0.81
Yellowness, b*[7]	8.55	8.60	8.71	8.44	0.22	0.84	0.27	0.74
Purge loss, %[8]	3.49	3.79	3.72	3.56	0.25	0.21	0.50	0.46
Chop								
Visual color	3.73	3.65	3.67	3.71	0.04	0.16	0.35	0.17
Visual marbling	2.52	2.13	2.48	2.18	0.07	< 0.001	< 0.01	0.37
Subjective firmness	2.96	2.99	3.04	2.91	0.26	0.76	0.22	0.69
Lightness, L*	54.87	55.23	55.28	54.82	0.33	0.43	0.32	0.83
Redness, a*	8.92	9.07	8.96	9.03	0.22	0.51	0.77	0.83
Yellowness, b*	7.99	8.37	8.24	8.12	0.19	0.09	0.61	0.99
Chop pH	5.71	5.70	5.71	5.70	0.05	0.20	0.49	0.94
Warner-Bratzler shear force, kg[9]	2.52	2.55	2.52	2.55	0.05	0.72	0.70	0.04
Cook loss, %	15.59	15.46	15.29	15.75	1.08	0.77	0.31	0.07

[1]Aged postmortem traits were evaluated 14 d postmortem

[2]NPPC color based on the 1999 standards measured in half point increments where 1 = palest, 6 = darkest.

[3]NPPC marbling based on the 1999 standards measured in half point increments where 1 = least amount of marbling, 6 = greatest amount of marbling.

[4]NPPC firmness based on the 1991 scale measured in half point increments where 1 = softest, 5 = firmest.

[5]L* measures darkness (0) to lightness (100; greater L* indicates a lighter color).

[6]a* measures redness (greater a* indicates a redder color).

[7]b* measures yellowness (greater b* indicates a more yellow color).

[8]Purge loss = [(1 d weight, kg - 14 d weight, kg) ÷ 1 d weight, kg] x 100.

[9]Warner-Bratzler shear force evaluated on chops cooked to 63° C

Table 2.10. Main effects of sire line and sex on fresh belly and ham characteristics.

	Sire Line		Sex			*P*-values		
Item	American	European	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	44	39	41	42				
Belly characteristics								
Thickness, cm[1]	3.10	3.33	3.42	3.02	0.05	< 0.001	< 0.001	0.83
Flop, cm	14.68	17.62	18.38	13.93	1.14	< 0.01	< 0.001	0.60
Ham characteristics								
Visual color[2]	2.30	3.10	2.69	2.70	0.12	< 0.001	0.92	0.21
Lightness, L*[3]	54.92	57.82	56.77	55.97	0.60	< 0.001	0.34	0.34
Redness, a*[4]	10.21	10.20	10.06	10.35	0.27	0.96	0.44	0.69
Yellowness, b*[5]	7.52	8.52	8.01	8.03	0.25	< 0.01	0.97	0.63
Ham pH	5.82	5.77	5.80	5.78	0.03	0.08	0.47	0.85

[1]Thickness was an average of measurements from 3 locations from the anterior to posterior.
[2]Visual ham color was based on 4 point visual scale where 1=darkest and 4=lightest.
[3]L* measures darkness (0) to lightness (100; greater L* indicates a lighter color).
[4]a* measures redness (greater a* indicates a redder color).
[5]b* measures yellowness (greater b* indicates a more yellow color).

Table 2.11. Interaction means of carcass characteristics, cutability, and loin and chop quality between sire line and sex.

	American		European			*P*-values		
Item	Barrow	Gilt	Barrow	Gilt	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	22	22	19	20				
Bone-in carcass cutting yield, %	73.64[b]	74.35[b]	73.18[b]	76.00[a]	1.51	0.26	< 0.01	0.05
1 d chop visual color	3.51[a]	3.45[a]	3.22[b]	3.45[a]	0.08	0.03	0.17	0.03
Warner-Bratzler shear force, kg	2.44[a]	2.60[a]	2.60[a]	2.49[a]	0.07	0.72	0.70	0.04

[a–b]Within a row, least squares means lacking a common superscript differ ($P \leq 0.05$).

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CHAPTER 3: EFFECTS OF DUROC SIRE LINES ON EARLY AND AGED PORK QUALITY

ABSTRACT

Duroc terminal sires are commonly used in commercial swine production, as they are known for producing animals that yield carcasses of high quality pork cuts, often sought after in both domestic and export markets. In order to meet the demands of different consumer markets, developing Duroc terminal sire lines that have the ability to improve both pork quality and growth performance data has become more important over the past few years. Therefore, the objective of this study was to evaluate the effect of 2 different Duroc sire lines and their effect on early and aged pork quality. The EB5 sire line (*n*=160) was intended for premium based programs, while the P26 sire line (*n*=144) was selected for competitive growth and performance. Sire line effect on carcass cutability, fresh ham and belly quality, and sliced bacon quality was also evaluated. The MIXED procedure of SAS was used to evaluate the fixed effects of sire line, sex, and the interaction between sire line and sex, and effects were considered significant at $P<0.05$. Average daily gain (**ADG**) did not differ ($P\geq0.08$) between sire line throughout any of the phases, but gain to feed (**G:F**) was slightly increased ($P=0.03$) overall (d0-98) in P26 sired pigs. Standardized fat-free lean (**FFL**) was increased ($P\leq0.01$) in P26 sired pigs at the University of Illinois (52.17 vs. 50.32%) and the federally inspected abattoir (50.11 vs. 48.85%) as compared to EB5 sired pigs. Bone-in carcass cutting yield, bone-in lean cutting yield, and boneless carcass cutting yield were increased ($P<0.001$) by 1.54, 1.92, and 1.69%, respectively, for P26 sired pigs. EB5 sired pigs had heavier marbled loins and chops as indicated by increased ($P\leq0.01$) early ventral visual marbling (2.39 vs. 2.11 units) and early chop visual marbling (2.82 vs. 2.55 units). EB5 sired pigs had darker, but less red, and less yellow loins as instrumental L*,

a*, and b* were decreased (*P*≤0.01) by 1.67, 1.11, and 1.27 units, respectively. Extractable chop lipid was increased (*P*<0.001) by 0.60% in EB5 sired pigs. Aged ventral and chop visual color did not differ (*P*=0.07) between sire lines, but aged ventral visual marbling was increased (*P*<0.001) by 0.28 units in EB5 sired pigs. EB5 sired pigs had increased (*P*<0.01) belly thickness (3.64 vs. 3.45 cm) and flop (22.20 vs. 18.70 cm) compared to P26 sired pigs. EB5 sired pigs had darker colored hams as indicated by decreased (*P*≤0.03) visual color score (3.15 vs. 2.84 units) and instrumental L* (57.23 vs. 54.68 units). Overall, P26 sired pigs had increased G:F, increased FFL, and increased cutting yields whereas EB5 sired pigs had heavier marbled loins and chops, thicker and firmer bellies, and darker hams.

INTRODUCTION

The Duroc pig is a significant and influential animal to the U.S. swine production industry as it is the second-most recorded breed in the United States (NPPC, 2011). Over the years, developing a Duroc-based terminal sire line that increases lean yields while improving meat quality has become extremely crucial to producers, packers, and the export market (Lonergan et al., 2001; Lowell et al., 2018; Schwab et al., 2007). It is important to keep in mind, however, that the pork industry has seen an upward trend in increasing HCW over the last 25 years, making the challenge to produce leaner hogs, with acceptable growth performance, and improved meat quality somewhat challenging (Cisneros et al., 1996; Edwards et al., 2003; Price et al., 2019). However, selective breeding techniques have allowed the current Duroc terminal sire lines used in crossbreeding scenarios for commercial pig production to be known for improved growth rates and meat quality (NPPC, 1995). While developing genetic lines of pigs selected for competitive lean growth and performance can improve growth performance and carcass characteristics, (Lonergan et al., 2001) reported selecting terminal sires for lean yields and competitive growth has the potential to negatively affect pork quality (Cameron et al., 1999). Therefore, the objective of this study was to compare pigs from 2 different Duroc sire lines; one being intended for premium based meat quality programs and the other intended for competitive growth and performance. Early and aged loin quality characteristics were evaluated; in addition to early ham, fresh belly, and sliced bacon characteristics.

MATERIALS AND METHODS

Pig Background

Pig background materials and methods were similar to chapter 2 except, pigs (304 total) from 2 different sire lines of Duroc ancestry (Choice Genetics, West Des Moines, IA) were used in the trial. The first sire line (EB5), selected to produce pork used in premium-based programs, provided 160 barrows and gilts. The second sire line (P26), selected to compete with commercial lines in terms of growth, provided 144 barrows and gilts. All pigs were housed in pens ($1.18 m^2$/pig) of 4 pigs of the same sex and sire line. Block 1 consisted of 80 EB5 sired pigs (40 barrows and 40 gilts) and 68 P26 sired pigs (28 barrows and 40 gilts). Block 2 consisted of 80 EB5 sired pigs (40 barrows and 40 gilts) and 76 P26 sired pigs (36 barrows and 40 gilts). A total of 37 pens were used in block 1 (10 barrow and gilt pens from EB5 sires, and 7 barrow and 10 gilt pens from P26 sires). A total of 39 pens were used in block 2 (10 barrow and gilt pens from EB5 sires, and 9 barrow and 10 gilt pens from P26 sires. Discrepancies in pen numbers were due to pig availability within each farrowing group.

A 3-phase, 98 d feeding program was used. Pens of pigs were fed a grower diet from d 0 to d 35, an early finisher diet from d 36 to d 70, and a late finisher diet from d 71 to d 98. Pigs were weighed at the end of each of the 3 feeding phases (d 35, 70, & 98). Day 98 for each block was considered the end of the feeding portion of the trial. On d 98, the heaviest pig from each pen (76 total pigs) was removed and transported to the University of Illinois Meat Science Laboratory (Urbana, IL) for slaughter on d 99. Also on d 99, the second heaviest and lightest pigs from each pen (152 total pigs) were removed and transported to a commercial scale federally inspected abattoir. The remaining pig (third heaviest) was slaughtered at the University of Illinois Meat Science Laboratory on d 101.

Postmortem Characteristics

Slaughter methods and carcass characteristics of pigs harvested at the University of Illinois and a federally inspected abattoir are similar to chapter 2. Additionally, carcass fabrication, early postmortem loin quality evaluation, and early postmortem ham quality evaluation methods were similar to chapter 2.

Early Postmortem Belly Quality

Early postmortem belly quality evaluation methods were similar to chapter 2 except, fresh bellies were evaluated for length at the midpoint of the latitudinal axis and width at the midpoint of the longitudinal axis. Belly thickness was calculated as the mean of 8 individual locations of the belly. Thickness at each location was determined by forcing a sharpened probe through the lean side of the belly. Measurements 1 to 4 were collected at the midpoint between the latitudinal axis and the dorsal edge at 20%, 40%, 60%, and 80% of the length of the belly starting at the anterior end. Measurements 5 to 8 were collected at the midpoint between the longitudinal axis and the ventral edge at 20%, 40%, 60%, and 80% of the length of the belly starting at the anterior end. After fresh belly quality had been evaluated, bellies were vacuum packaged and stored at -34°C for approximately 106 d until they were manufactured into bacon.

Aged Postmortem Loin Quality Evaluation

Aged postmortem loin quality evaluation methods were similar to chapter 2 except, chop 1 was trimmed free of all subcutaneous fat and secondary muscles, packaged in Whirl-Pak bags (Nasco, Ft. Atkinson, WI), and stored at -2°C until determination of moisture and extractable lipid. Chop 2 was used to determine 63°C cook loss, Warner-Bratzler Shear Force (**WBSF**) and cooked proximate analysis (moisture and extractable lipid). Chop 3 was used to determine 71°C cook loss, WBSF, and cooked proximate analysis (moisture and extractable lipid). Chop 4 was vacuum packaged and stored at -2°C until trained sensory panels could were conducted. Chop 5 was vacuum packaged and stored at -2°C until consumer sensory panels could were conducted. Chop 6 was vacuum packaged and stored at -2°C as a backup sample.

Cook Loss and Warner-Bratzler Shear Force

Cook loss and WBSF methods were similar to chapter 2 except, chop 2 was cooked, on one side, to an internal temperature of 31°C, then flipped and cooked until a final internal temperature of 63°C. Chop 3 was cooked, on one side, to an internal temperature of 36°C, then flipped and cooked to a final internal temperature of 71°C.

Raw Chop Proximate Composition

Raw chop proximate composition methods were similar to chapter 2.

Bacon Manufacturing and Slicing

Frozen, vacuum packaged bellies were allowed to thaw at 4°C for approximately 6 d. Thawed bellies were skinned, yielding an NAMP #409 skinless belly, and then weighed to determine initial weight (green weight). Bellies were repackaged and transported in a refrigerated truck to a USDA federally inspected bacon manufacturing facility for further processing. Bellies were injected with a typical commercial cure solution formulated to deliver

1.5% sodium chloride (salt) in the final product with a target pump uptake of 13%. Bellies were weighed immediately after injection to calculate pump uptake using the following equation:

Pump Uptake = [(pumped weight – initial weight) / initial weight] × 100

Injected bellies were hung on smoke house racks, from the anterior end using bacon combs inserted through the medial side of the belly, and thermally processed to an internal temperature of 53.3°C. Bellies were chilled for approximately 24 h before slicing, and ultimately reached an internal temperature between -5.6°C and -4.4°C. Chilled bellies were weighed to calculate cooked yield using the following equation:

Cooked yield = [(cooked weight – initial weight) / initial weight] × 100

Bellies were pressed and then sliced, anterior end first, to obtain a target of 22 to 27 slices per kg (10 to 12 slices per pound). Slices were sorted by trained personnel, based on grading procedures of the manufacturer, to remove incomplete slices, end pieces, and slices of unacceptable quality. Sliced bacon slabs were placed on U-boards and vacuum packaged individually such that anatomical orientation was maintained with 1 sliced bacon slab per package. Sliced bacon slabs were then transported to the University of Illinois Meat Science Laboratory for further analysis.

Statistical Analysis

Statistical analysis procedures were similar to chapter 2 except, pen (76 total) served as the experimental unit for all fixed variables.

RESULTS

Growth Performance, Carcass Characteristics, and Cutability

Birth weight (P=0.17) and wean weight (P=0.70) did not differ between sire lines (Table 3.1). During phase 1 (d0-35), ADG, average daily feed intake (**ADFI**), and G:F did not differ ($P \geq 0.25$) between sire lines. However, there was a sire line by sex interaction (P=0.03) as EB5 and P26 barrows had increased ADFI during phase 1. During phase 2 (d36-70), ADFI was increased (*P*=0.01) by 0.07 kg/d for EB5 sired pigs. ADG and G:F did not differ (*P*≥0.19) between sire lines during phase 2. During phase 3 (d71-98) and overall, G:F was increased (*P*≤0.05) in P26 sired pigs compared to EB5 sired pigs. During phase 3 and overall, ADG and ADFI did not differ (*P*≥0.08) between sire lines.

Of the pigs harvested at the University (first and third heaviest), ELW, HCW, carcass yield, and LEA did not differ (*P*≥0.06) between sire lines (Table 3.2). Tenth rib back fat was increased (*P*<0.001) by 0.38 cm in EB5 sired pigs. P26 sired pigs had an increased (*P*<0.001) FFL by 1.85% units compared to EB5 sired pigs. Of the pigs harvested at the federally inspected abattoir (second heaviest and lightest), HCW did not differ between sire lines (*P*≥0.75). However, EB5 sired pigs had increased (*P*<0.01) last rib back fat by 0.33 cm, while P26 sired pigs had an increased (*P*<0.01) FFL lean by 1.26% units.

The cutability of each primal and of the carcass overall are displayed in tables 3.3 (shoulder), 3.4 (loin), 3.5 (ham), 3.6 (belly and other cuts), 3.7 (overall). P26 sired pigs had heavier (*P*<0.01) whole shoulders (13.04 vs. 12.59 kg), bone-in Boston butts (4.12 vs. 3.93 kg), and boneless Boston butts (3.80 vs. 3.66 kg). P26 sired pigs also had heavier (*P*<0.001) bone-in picnics (5.53 vs. 5.24 kg), boneless picnics (4.03 vs. 3.79 kg), and boneless shoulders (7.84 vs. 7.44 kg). Percent of chilled side weight was increased (*P*<0.001) by 0.67% for whole shoulders, 0.30% for bone-in Boston butts, 0.45% for bone-in picnics, 0.43% for boneless picnics, and 0.67% for boneless shoulders in P26 sired pigs. Percent of chilled side weight for boneless Boston butts was increased (*P*<0.01) by 0.23% for P26 pigs. EB5 sired pigs had an increased (*P*=0.05) percent of chilled side for jowls by 0.10% and heavier clear plates 0.04 kg. EB5 pigs had increased percent of chilled side weight for clear plates by 0.10% compared to P26 sired pigs.

P26 sired pigs had heavier ($P \leq 0.01$) trimmed loins (11.13 vs. 10.80 kg), Canadian backs (3.78 vs. 3.49 kg), tenderloins (0.47 vs. 0.45 kg), sirloins (0.88 vs. 0.82 kg), and boneless loins (5.14 vs. 4.76 kg). There was a sire line by sex interaction as both P26 barrows and P26 gilts had increased weights for Canadian backs ($P=0.05$) and boneless loins ($P=0.04$). Whole loin weight did not did differ between sire lines ($P=0.10$) but, percent of chilled side weight for whole loins was increased ($P<0.001$) in EB5 sired pigs by 0.70 kg. P26 sired pigs had increased ($P \leq 0.03$) percent of chilled side for trimmed loins by 0.45%, Canadian backs by 0.54%, tenderloins by 0.03%, sirloins by 0.10%, and boneless loins by 0.67%. A sire line by sex interaction ($P=0.01$) existed as P26 sired gilts had an increased percent of chilled side weight for Canadian backs by 0.69% and for boneless loins by 0.97%.

P26 sired pigs had heavier ($P \leq 0.01$) whole hams (11.98 vs. 11.63 kg), trimmed hams (10.21 vs. 9.76 kg), outside hams (2.62 vs. 2.49 kg), inner shanks (0.69 vs. 0.66 kg), lite butts (0.29 vs. 0.25 kg), and boneless hams (6.83 vs. 6.46 kg). P26 sired pigs also had increased ($P \leq 0.02$) percent of chilled side for whole hams by 0.47%, trimmed hams by 0.72%, outside ham by 0.21%, knuckles by 0.20%, inner shanks by 0.04%, lite butts by 0.09%, and boneless hams by 0.65%.

Natural fall belly weight did not differ ($P=0.24$) between sire lines however, percent of chilled side weight for natural fall bellies was increased ($P=0.01$) by 0.36% in EB5 sired pigs. Sparerib weight and percent of chilled side weight for spareribs was increased ($P<0.001$) in P26 sired pigs by 0.13 kg and 0.22%. Standardized trim weight and percent of chilled side weight for standardized trim was increased ($P=0.02$) in EB5 sired pigs by 0.04 kg and 0.08%. Leaf fat weight and percent of chilled side weight for leaf fat was increased (*P*≤0.01) by 0.13 kg and 0.27% in EB5 sired pigs. Front and back foot weight was increased (*P*=0.01) by 0.04 kg in P26 sired pigs.

P26 sired pigs had increased (*P*<0.001) bone-in carcass cutting yield by 1.54%, bone-in lean cutting yield by 1.92%, and boneless carcass cutting yield by 1.69%. A sire line by sex interaction indicated P26 gilts had an increased (*P*=0.02) boneless carcass cutting yield by 1.99% as compared to EB5 sired pigs.

Pork Quality

EB5 sired pigs had increased (*P*<0.01) early ventral visual marbling by 0.28 units (Table 3.8). P26 sired pigs had increased (*P*=0.01) early ventral L* by 1.67 units and increased (*P*<0.001) early ventral a* (10.12 vs. 9.01 units) and b* (8.35 vs. 7.08 units). Early ventral visual color, subjective firmness, and ventral pH did not differ (*P*≥0.06) between sire lines. Early visual chop marbling and extractable lipid of chops cooked to 71˚ C was increased (*P*=0.01) by 0.27 units and 0.52% in EB5 sired pigs. Early chop subjective firmness (3.00 vs. 2.67 units; *P*<0.01) was increased in EB5 sired pigs. Extractable lipid of chops cooked to 63˚ C (4.51 vs. 3.87%) and raw extractable lipid (3.74 vs. 3.14%) was increased (*P*<0.001) in EB5 sired pigs. Raw moisture was increased (*P*<0.01) in P26 sired pigs by 0.53%. Early chop visual color, chop L*, a*, and b* did not differ (*P*≥0.10) did not differ between sire lines.

Aged ventral visual marbling (2.64 vs. 2.36 units; *P*<0.001), subjective firmness (3.43 vs. 3.22 units; *P*=0.04), and aged ventral pH scores were increased (5.70 vs. 5.65 units; *P*<0.01) in EB5 sired pigs (Table 3.9). Aged ventral L* was increased (*P*=0.04) by 1.16 units and instrumental b* was increased (*P*=0.01) by 0.71 units in P26 sired pigs. P26 barrows had increased (*P*=0.05) aged ventral b* values by 1.04 units indicated by a sex by sire line interaction. Aged ventral visual color, ventral a*, and purge loss did not differ (*P*≥0.07) between sire lines. Aged chop visual color, marbling, subjective firmness, L*, a*, and b* did not differ (*P*≥0.07) between sire lines. WBSF and cook loss of chops cooked to either 63˚ C or 71˚ C did not differ (*P*≥0.50) between sire lines.

Belly length did not differ (*P*=0.28) between sire lines. Belly width was increased (*P*<0.01) by 1.09 cm in P26 sired pigs (Table 3.10). Belly thickness and flop was increased (*P*<0.01) by 0.19 cm and 3.5 cm in the EB5 sired pigs.

Early ham visual color score and instrumental L* was increased (*P*≤0.03) by 0.31 units and 2.55 units in P26 sired pigs (Table 3.11). Early ham pH was increased (*P*<0.01) by 0.09 units in EB5 sired pigs. Ham instrumental a* and b* did not differ (*P*=0.09) between sire lines.

Cured Sliced Belly Quality

There was a sire line by sex interaction (*P*=0.01) for belly trim loss as P26 sired gilts had an increased trim loss by 15.52% compared with EB5 sired pigs (Table 3.12). Natural fall weight, green weight, thaw loss, trim loss, pump uptake, cooked yield, slice yield (green) and slice yield (cooked) did not differ (*P*≥0.20) between sire lines.

EB5 sired pigs had wider (*P*=0.04) blade slices by 0.15 cm and a greater (*P*=0.04) total slice area by 3.46 cm^2 (Table 3.13). There was a sire line by sex interaction (*P*=0.02) for middle slice length and middle slice primary lean as both EB5 barrows and P26 gilts had longer slices and greater areas of primary lean than EB5 gilts and P26 barrows. A sire line by sex interaction (*P*=0.04) indicated EB5 barrows had wider middle slices than EB5 gilts, P26 barrows, and P26 gilts by 0.19 cm. Flank slice secondary lean was increased (18.31 vs. 16.17 cm^2; *P*=0.01) in P26 sired pigs. P26 sired pigs had an increased (*P*<0.001) lean to fat ratio (0.83 vs. 0.70) and percentage of lean (40.25 vs. 36.98%). EB5 sired pigs had an increased (P<0.001) percent of fat by 3.84% as compared to P26 sired pigs.

DISCUSSION

Duroc-based terminal sires are often used in today's commercial swine crossbreeding scenarios as they improve fresh pork quality and are of value in export markets as they meet consumer demands in other countries (Lowell et al., 2018). However, over the last 25 years, the average pork HCW has increased to 96.5 kg (USDA, 2019) and in turn, has caused some concern regarding the production of lean hogs with acceptable growth performance and pork quality (Cisneros et al., 1996; Edwards et al., 2003). In order to do this, multi trait selection of Duroc sire is of the utmost importance. Thus, the ultimate goal of this study was to evaluate the differences between two different Duroc sire lines; one intended for premium based programs and the other selected for competitive growth and performance. Economically, these traits are of high significance when considering breeding boars to females due to sheer economic breeding value (Miar et al., 2014).

The P26 terminal sire used in this trial was selected for competitive growth; although, interestingly enough, there were no significant differences in birth weight, weaning weight, or ADG throughout any of the phases or overall. Although ADG was not affected, G:F was increased for P26 pigs during phase 3 and throughout the entire trial which is an important financial factor for producers. Considering feed costs make up nearly 2/3 of production costs, the importance of selecting animals that can efficiently convert feed to kilograms is extremely crucial (Hoque et al., 2009). There were no differences in ELW, HCW, carcass yield, or LEA between the two sire lines. However, P26 pigs were nearly 0.5 cm leaner at the 10^{th} rib than EB5 leading to an increase in FFL. In a similar study where Durocs were selected for lean growth efficiency, the lean growth sire line had decreased tenth rib back fat and increased percent lean agreeing with the present study (Lonergan et al., 2001). P26 sired pigs had increased bone-in carcass cutting yield, bone-in lean cutting yield, and boneless carcass cutting yield compared with the EB5 sired pigs. Therefore, in terms of growth performance, carcass characteristics and cutability, the P26 pig was superior to the EB5. In terms of G:F, EB5 sired pigs were only slightly less efficient, but had considerably more back fat ultimately decreasing FFL when compared to P26 sired pigs.

In terms of loin quality, EB5 pigs had darker, heavier marbled, and firmer loins at both early and aged time points. Furthermore, EB5 pigs had increased early visual marbling and subjective firmness in the chop face and greater extractable lipid. Ultimate pH was also increased in loins from EB5 pigs. However, WBSF of chops cooked to 63˚ C and 71˚ C did not differ between sire lines. Similar to loin results, EB5 sired pigs also had darker hams. While P26 sired pigs had wider bellies when compared to EB5 pigs, belly thickness and flop were increased in EB5 pigs. These differences did not alter commercial bacon processing characteristics, but EB5 pigs had wider slices with increased total slice area. Therefore, in terms of pork quality, EB5 pigs held the advantage. Although, EB5 pigs held the advantage in terms of meat quality, P26 pigs were of acceptable ultimate pH (both early and aged) and considered tender as (< 3.09 kg).

CONCLUSION

Duroc pigs are often selected to improve pork quality characteristics however; genetic advancements have been made in the swine industry allowing terminal sires to improve both pork quality and growth performance. This study aimed to evaluate Durocs and their effect on loin, ham, and belly quality. Overall, P26 sired pigs, which were selected for competitive growth and performance, were superior to EB5 sired pigs in terms of growth performance, carcass characteristics, and cutability. For producers and exporters that value lean meat yield, the P26 sire line is the superior choice. However, EB5 sired pigs, intended for premium meat based programs, produced higher quality pork in terms of both pork loin and belly quality. Though these pigs do not grow as fast or efficiently, if meat quality is at a premium, the EB5 sire line is the preferred choice.

TABLES

Table 3.1. Main effects of sire line and sex on growth characteristics

	Sire line		Sex			*P*-values		
Item	EB5	P26	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	36	36	40				
Birth wt, kg	1.59	1.64	1.62	1.61	0.05	0.17	0.70	0.32
Weaning wt, kg	6.46	6.42	6.31	6.56	0.23	0.70	0.02	0.34
Phase 1 (d0-35)[1]								
BW d0, kg	26.51	26.60	26.67	26.45	0.32	0.30	0.02	0.82
ADG, kg/d	0.95	1.04	1.09	0.90	0.06	0.30	0.02	0.19
ADFI, kg/d	2.03	2.04	2.13	1.94	0.09	0.69	< 0.0001	0.03
G:F	0.47	0.53	0.53	0.47	0.04	0.25	0.20	0.28
BW d35, kg	59.27	59.62	61.03	57.86	1.04	0.61	< 0.0001	0.16
Phase 2 (d36-70)								
ADG, kg/d	1.07	1.04	1.11	1.00	0.06	0.19	< 0.0001	0.33
ADFI, kg/d	3.04	2.97	3.25	2.75	0.04	0.01	< 0.0001	0.17
G:F	0.35	0.35	0.34	0.36	0.02	0.93	0.02	0.08
BW d70, kg	96.86	95.97	100.01	92.81	3.20	0.30	< 0.0001	0.92
Phase 3 (d71-98)								
ADG, kg/d	1.09	1.15	1.19	1.04	0.11	0.08	< 0.0001	0.32
ADFI, kg/d	3.50	3.50	3.76	3.24	0.21	0.89	< 0.0001	0.21
G:F	0.31	0.33	0.32	0.32	0.01	0.05	0.55	0.09
BW d98, kg	127.27	128.10	133.35	122.02	0.60	0.31	< 0.0001	0.21
Overall (d0-98)								
ADG, kg/d	1.03	1.04	1.09	0.98	0.01	0.25	< 0.0001	0.15
ADFI, kg/d	2.81	2.78	2.99	2.60	0.07	0.14	< 0.0001	0.37
G:F	0.37	0.37	0.36	0.38	0.01	0.03	< 0.001	0.50

[1]Pigs were approximately 10 wks old on d0.

Table 3.2. Main effects of sire line and sex on carcass characteristics

Item	Sire Line		Sex		SEM	*P*-values		
	EB5	P26	Barrows	Gilts		Sire Line	Sex	Sire line × Sex
Pens, n	40	36	36	40				
University of Illinois[1]								
Ending live weight, kg	127.81	129.44	133.81	123.45	0.64	0.07	< 0.001	0.95
HCW, kg[2]	100.84	101.84	105.77	96.91	0.53	0.17	< 0.001	0.88
Carcass yield, %	78.88	78.67	79.06	78.49	0.24	0.18	< 0.001	0.39
Loin muscle area, cm^2	43.92	45.90	44.63	45.19	0.76	0.06	0.59	0.62
10th rib back fat depth, cm	2.41	2.03	2.37	2.06	0.07	< 0.001	0.00	0.88
Standardized fat-free lean, %[3]	50.32	52.17	50.36	52.13	0.33	< 0.001	< 0.001	0.58
Federally Inspected Abattoir[4]								
HCW, kg	93.75	93.19	95.10	91.84	1.28	0.75	0.07	0.82
Last rib back fat depth, cm	3.18	2.85	3.22	2.81	0.15	< 0.01	< 0.001	0.88
Standardized fat-free lean, %[5]	48.85	50.11	48.58	50.38	0.61	< 0.01	< 0.001	0.66

[1]Values are based on data collected from the first and third heaviest pig in each pen.

[2]HCW includes the left and right sides with leaf fat and standardized trim still intact.

3Standardized fat-free lean = ((8.588 + (0.465 x HCW, lb) - (21.896 x fat depth, in) + (3.005 x LTL area, in^2)) ÷ HCW) x 100, (Burson and Berg, 2001).

[4]Values are based on data collected from the second heaviest and lightest pig in each pen.

[5]Standardized fat-free lean = ((23.568 + (0.503 x HCW, lb) - (21.348 x fat thickness, in))÷HCW) x 100, (Burson and Berg, 2001).

Table 3.3. Main effects of sire line and sex on shoulder carcass cuts

	Sire Line		Sex			*P*-values		
Item	EB5	P26	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	36	36	40				
Whole shoulder, kg	12.59	13.04	13.38	12.25	0.17	< 0.01	< 0.001	0.22
% chilled side wt	25.53	26.20	25.82	25.91	0.20	< 0.001	0.65	0.27
Bone-in Boston, kg	3.93	4.12	4.19	3.86	0.10	< 0.01	< 0.001	0.56
% chilled side wt	7.98	8.28	8.10	8.16	0.16	< 0.001	0.44	0.83
Bone-in picnic, kg	5.24	5.53	5.61	5.16	0.06	< 0.001	< 0.001	0.71
% chilled side wt	10.61	11.06	10.81	10.86	0.08	< 0.001	0.66	0.84
Boneless Boston, kg	3.66	3.80	3.89	3.57	0.09	< 0.01	< 0.001	0.61
% chilled side wt	7.42	7.65	7.51	7.55	0.15	< 0.01	0.60	0.91
Boneless picnic, kg	3.79	4.03	4.09	3.73	0.04	< 0.001	< 0.001	0.76
% chilled side wt	7.68	8.11	7.90	7.88	0.06	< 0.001	0.83	0.88
Neckbones, kg	1.03	1.06	1.07	1.02	0.02	0.38	0.06	0.67
% chilled side wt	2.09	2.12	2.07	2.15	0.04	0.60	0.17	0.82
Jowl, kg	1.53	1.49	1.60	1.42	0.04	0.16	< 0.001	0.49
% chilled side wt	3.09	2.99	3.08	3.00	0.11	0.05	0.12	0.53
Clear plate, kg	0.89	0.85	0.95	0.79	0.04	0.05	< 0.001	0.19
% chilled side wt	1.80	1.70	1.83	1.67	0.07	0.02	< 0.001	0.14
Boneless shoulder, kg[1]	7.44	7.84	7.98	7.30	0.13	< 0.001	< 0.001	0.63
% chilled side wt	15.09	15.76	15.41	15.43	0.18	< 0.001	0.86	0.98

[1]Boneless shoulder = boneless Boston butt (NAMP # 406A), kg + boneless picnic (NAMP #405A), kg.

Table 3.4. Main effects of sire line and sex on loin carcass cuts

Item	Sire Line		Sex		SEM	*P*-values		
	EB5	P26	Barrows	Gilts		Sire Line	Sex	Sire line × Sex
Pens, n	40	36	36	40				
Whole loin, kg	13.72	13.50	14.31	12.90	0.23	0.10	< 0.001	0.72
% chilled side wt	27.78	27.08	27.63	27.23	0.30	< 0.001	0.02	0.45
Trimmed loin, kg	10.80	11.13	11.28	10.66	0.08	< 0.01	< 0.001	0.54
% chilled side wt	21.92	22.37	21.77	22.51	0.10	< 0.01	< 0.001	0.17
Canadian Back, kg	3.49	3.78	3.68	3.59	0.04	< 0.001	0.03	0.05
% chilled side wt	7.08	7.62	7.11	7.56	0.06	< 0.001	< 0.001	0.01
Tenderloin, kg	0.45	0.47	0.47	0.46	0.01	0.01	0.25	0.39
% chilled side wt	0.92	0.95	0.90	0.97	0.01	0.03	< 0.001	0.28
Sirloin, kg	0.82	0.88	0.86	0.85	0.01	< 0.01	0.51	0.14
% chilled side wt	1.67	1.77	1.66	1.79	0.03	0.01	< 0.001	0.08
Backribs, kg	0.88	0.90	0.92	0.86	0.03	0.08	< 0.001	0.97
% chilled side wt	1.78	1.82	1.78	1.81	0.05	0.18	0.35	0.96
Backbone, kg	2.09	2.11	2.15	2.06	0.05	0.57	0.05	0.45
% chilled side wt	4.24	4.25	4.14	4.35	0.11	0.92	0.01	0.47
Boneless loin, kg[1]	4.76	5.14	5.01	4.89	0.06	< 0.001	0.05	0.04
% chilled side wt	9.67	10.34	9.67	10.34	0.08	< 0.001	< 0.001	0.01

[1]Boneless loin = Canadian back loin (NAMP #414), kg + tenderloin (NAMP #415A), kg + sirloin (NAMP #413D), kg.

Table 3.5. Main effects of sire line and sex on ham carcass cuts

	Sire Line		Sex			*P*-values		
Item	EB5	P26	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	36	36	40				
Whole ham, kg	11.63	11.98	12.06	11.54	0.09	< 0.001	< 0.001	0.78
% chilled side wt	23.62	24.09	23.30	24.41	0.29	< 0.001	< 0.001	0.69
Trimmed ham, kg	9.76	10.21	10.13	9.85	0.12	< 0.001	< 0.01	0.89
% chilled side wt	19.84	20.56	19.56	20.84	0.35	< 0.001	< 0.001	0.50
Inside ham, kg	1.73	1.79	1.75	1.77	0.02	0.10	0.54	0.18
% chilled side wt	3.53	3.61	3.39	3.75	0.05	0.26	< 0.001	0.26
Outside ham, kg	2.49	2.62	2.58	2.53	0.04	0.01	0.30	0.22
% chilled side wt	5.07	5.28	4.99	5.36	0.10	0.02	< 0.001	0.13
Knuckle, kg	1.33	1.44	1.40	1.36	0.02	< 0.001	0.03	0.43
% chilled side wt	2.70	2.90	2.71	2.89	0.05	< 0.001	< 0.001	0.18
Inner shank, kg	0.66	0.69	0.69	0.66	0.01	0.01	0.01	0.60
% chilled side wt	1.34	1.38	1.33	1.39	0.03	0.02	< 0.01	0.90
Lite butt, kg	0.25	0.29	0.26	0.27	0.01	< 0.001	0.31	0.92
% chilled side wt	0.50	0.59	0.51	0.58	0.03	< 0.001	< 0.001	0.85
Boneless ham, kg[1]	6.46	6.83	6.69	6.60	0.07	< 0.001	0.17	0.73
% chilled side wt	13.13	13.78	12.92	13.99	0.20	< 0.001	< 0.001	0.28

[1]Boneless ham = inside ham (NAMP #402F), kg + outside ham (NAMP #402E), kg + knuckle (NAMP #402H), kg + lite butt, kg+ inner shank, kg.

Table 3.6. Main effects of sire line and sex on belly and miscellaneous cuts

	Sire Line		Sex			*P*-values		
Item	EB5	P26	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	36	36	40				
Natural fall belly, kg	7.30	7.19	7.66	6.84	0.07	0.24	< 0.001	0.95
% chilled side wt	14.78	14.42	14.42	14.41	0.13	0.01	< 0.01	0.78
Spareribs, kg	1.75	1.88	1.88	1.75	0.05	< 0.001	< 0.001	0.64
% chilled side wt	3.56	3.78	3.63	3.71	0.11	< 0.001	0.04	0.98
Miscellaneous Cuts								
Standardized trim, kg	0.18	0.14	0.19	0.13	0.03	0.02	< 0.001	0.44
% chilled side wt	0.36	0.28	0.37	0.27	0.05	0.02	< 0.01	0.39
Leaf fat, kg	0.93	0.80	1.01	0.72	0.11	< 0.01	< 0.001	0.59
% chilled side wt	1.87	1.60	1.95	1.52	0.20	< 0.001	< 0.001	0.49
Front and back foot, kg	1.11	1.15	1.16	1.11	0.01	0.01	< 0.001	0.58
% chilled side wt	2.26	2.31	2.23	2.35	0.02	0.07	< 0.001	0.90

Table 3.7. Main effects of sire line and sex on carcass cutability

	Sire Line		Sex			*P*-values		
Item	EB5	P26	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	36	36	40				
Bone-in carcass cutting yield, %[1]	75.16	76.70	75.06	76.80	0.29	< 0.001	< 0.001	0.13
Bone-in lean cutting yield, %[2]	60.36	62.28	60.26	62.38	0.23	< 0.001	< 0.001	0.28
Boneless carcass cutting yield, %[3]	52.68	54.37	52.79	54.25	0.16	< 0.001	< 0.001	0.02

[1]Bone-in carcass cutting yield = [(trimmed ham, kg + bone-in Boston, kg + bone-in picnic, kg + trimmed loin, kg + natural fall belly, kg) ÷ left side chilled weight, kg] x 100.

[2]Bone-in lean cutting yield = [(trimmed ham, kg + bone-in Boston, kg + bone-in picnic, kg + trimmed loin, kg) ÷ left side chilled weight, kg] x 100.

[3]Boneless carcass cutting yield = [(inside ham, kg + outside ham, kg + knuckle, kg, + lite butt, kg + inner shank, kg) + (Canadian back loin, kg + tenderloin, kg + sirloin, kg) + (boneless Boston, kg + boneless picnic, kg) + (belly, kg)) ÷ left side chilled weight] x 100.

Table 3.8. Main effects of sire line and sex on early loin and chop face quality and color[1]

	Sire Line		Sex			*P*-values		
Item	EB5	P26	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	36	36	40				
Loin								
Visual color[2]	3.81	3.68	3.79	3.71	0.06	0.15	0.35	0.63
Visual marbling[2]	2.39	2.11	2.38	2.12	0.06	< 0.01	< 0.01	0.60
Subjective firmness[3]	3.19	2.96	3.15	3.00	0.23	0.06	0.23	0.52
Lightness, L*[4]	49.72	51.39	50.54	50.57	1.02	0.01	0.95	0.89
Redness, a*[4]	9.01	10.12	9.63	9.50	0.76	< 0.001	0.64	0.12
Yellowness, b*[4]	7.08	8.35	7.83	7.61	0.79	< 0.001	0.42	0.15
Ventral pH	5.68	5.64	5.68	5.63	0.02	0.06	0.01	0.86
Chop								
Visual color	3.84	3.79	3.89	3.74	0.05	0.45	0.02	0.42
Visual marbling	2.82	2.55	2.82	2.54	0.07	0.01	0.01	0.51
Subjective firmness	3.00	2.67	2.99	2.68	0.08	< 0.01	0.01	0.46
Lightness, L*	56.12	57.33	56.63	56.86	1.09	0.10	0.80	0.94
Redness, a*	8.98	8.78	8.99	8.77	0.24	0.42	0.36	0.11
Yellowness, b*	6.82	7.25	7.19	6.88	0.23	0.11	0.25	0.13
63° C Moisture, %	66.07	66.30	66.28	66.09	0.17	0.34	0.41	0.30
63° C Extractable Lipid, %	4.51	3.87	4.49	3.92	0.26	< 0.001	< 0.01	0.14
71° C Moisture, %	64.51	64.77	64.44	64.84	0.25	0.39	0.20	0.62
71° C Extractable Lipid, %	4.92	4.40	5.02	4.30	0.25	0.01	< 0.001	0.36
Raw Moisture, %	72.38	72.91	72.56	72.73	0.24	< 0.01	0.37	0.42
Raw Extractable Lipid, %	3.74	3.14	3.75	3.14	0.18	< 0.001	< 0.001	0.18

[1]Early postmortem traits were evaluated 1 d postmortem;
[2]NPPC color based on the 1999 standards measured in half point increments where 1 = palest, 6 = darkest and where 1 = least amount of marbling, 6 = greatest amount of marbling.
[3]NPPC firmness based on the 1991 scale measured in half point increments where 1 = softest, 5 = firmest.
[4]L* measures darkness (0) to lightness (100; greater L* indicates a lighter color), a* measures redness (greater a* indicates a redder color), b* measures yellowness (greater b* indicates a more yellow color).

Table 3.9. Main effects of sire line and sex on aged loin and chop quality[1]

	Sire Line		Sex			*P*-values		
Item	EB5	P26	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	36	36	40				
Loin								
Visual color[2]	3.83	3.67	3.81	3.69	0.07	0.07	0.17	0.91
Visual marbling[3]	2.64	2.36	2.63	2.38	0.06	< 0.001	< 0.01	0.81
Subjective firmness[4]	3.43	3.22	3.45	3.20	0.07	0.04	0.01	0.97
Lightness, L*[5]	52.01	53.17	52.82	52.36	0.41	0.04	0.42	0.27
Redness, a*[6]	8.84	9.16	9.19	8.81	0.22	0.14	0.07	0.08
Yellowness, b*[7]	7.65	8.36	8.27	7.33	0.18	0.01	0.03	0.05
Purge loss, %[8]	8.64	9.08	8.28	9.45	0.81	0.31	0.01	0.17
Ventral pH	5.70	5.65	5.69	5.65	0.02	< 0.01	0.02	0.72
Chop								
Visual color	4.01	3.90	3.97	3.94	0.14	0.07	0.71	0.78
Visual marbling	2.66	2.48	2.77	2.38	0.17	0.08	< 0.001	0.10
Subjective firmness	2.65	2.48	2.51	2.63	0.08	0.11	0.27	0.42
Lightness, L*	53.60	54.61	54.23	53.98	0.93	0.17	0.73	0.62
Redness, a*	9.55	9.70	9.67	9.58	0.49	0.48	0.67	0.50
Yellowness, b*	8.20	8.39	8.35	8.24	0.56	0.40	0.63	0.49
Warner-Bratzler shear force 63° C, kg	2.74	2.79	2.69	2.84	0.05	0.50	0.05	0.16
Cook Loss 63° C, %	18.53	18.81	17.94	19.40	0.41	0.61	0.01	0.93
Warner-Bratzler shear force 71° C, kg	3.11	3.09	3.11	3.09	0.08	0.82	0.83	0.85
Cook Loss 71° C, %	23.30	23.48	23.40	23.37	1.44	0.81	0.98	0.26

[1]Aged postmortem traits were evaluated 14 d postmortem

[2]NPPC color based on the 1999 standards measured in half point increments where 1=palest, 6=darkest.

[3]NPPC marbling based on the 1999 standards measured in half point increments where 1=least amount of marbling, 6=greatest amount of marbling.

[4]NPPC firmness based on the 1991 scale measured in half point increments where 1=softest, 5=firmest.

[5]L* measures darkness (0) to lightness (100; greater L* indicates a lighter color).

[6]a* measures redness (greater a* indicates a redder color).

[7]b* measures yellowness (greater b* indicates a more yellow color).

[8]Purge loss = [(1 d weight, kg - 14 d weight, kg) ÷ 1 d weight, kg] x 100.

Table 3.10. Main effects of sire line and sex on fresh belly characteristics

	Sire Line		Sex			*P*-values		
Item	EB5	P26	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	36	36	40				
Length, cm	68.73	68.36	69.41	67.68	0.60	0.28	< 0.001	0.49
Width, cm	26.67	27.76	27.37	27.06	0.50	< 0.01	0.40	0.25
Thickness, cm[1]	3.64	3.45	3.77	3.32	0.08	< 0.01	< 0.001	0.35
Flop, cm	22.20	18.70	22.60	18.57	0.97	< 0.01	< 0.001	0.99

[1]Thickness was an average of measurements from 8 locations from the anterior to posterior.

Table 3.11. Effects of sire line and sex on 1 d fresh ham characteristics

	Sire Line		Sex			*P*-values		
Item	EB5	P26	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	36	36	40				
Visual color[1]	2.84	3.15	3.05	2.94	0.17	0.03	0.42	0.64
Lightness, L*[2]	54.68	57.23	55.50	56.42	0.92	0.02	0.39	0.28
Redness, a*[3]	10.41	11.13	10.59	10.95	0.30	0.09	0.39	0.34
Yellowness, b*[4]	7.88	8.73	8.11	8.50	0.43	0.09	0.45	0.24
Ham pH	5.67	5.58	5.64	5.60	0.13	< 0.01	0.15	0.80

[1]Visual ham color was based on 4 point visual scale where 1=darkest and 4=lightest.

[2]L* measures darkness (0) to lightness (100; greater L* indicates a lighter color).

[3]a* measures redness (greater a* indicates a redder color).

[4]b* measures yellowness (greater b* indicates a more yellow color).

Table 3.12. Main effects of sire line and sex on cured belly and bacon characteristics

Item	Sire line		Sex		SEM	*P* - values		
	EB5	P26	Barrows	Gilts		Sire line	Sex	Sire Line × Sex
Pens, n	40	36	36	40				
Natural fall wt, kg	7.30	7.19	7.66	6.84	0.07	0.25	< 0.0001	0.95
Thawed wt, kg	7.22	7.10	7.57	6.75	0.07	0.22	< 0.0001	0.96
Thaw loss, %	1.10	1.24	1.06	1.28	0.08	0.24	0.06	0.65
Green wt, kg	6.19	6.08	6.53	5.74	0.06	0.20	< 0.0001	0.63
Trim loss, %	14.26	14.53	13.75	15.04	0.26	0.32	< 0.0001	0.01
Pumped wt, kg	6.90	6.79	7.29	6.41	0.07	0.27	< 0.0001	0.55
Pump uptake, %	10.22	10.51	10.31	10.42	0.20	0.64	0.64	0.69
Cooked wt, kg	6.29	6.16	6.64	5.81	0.07	0.15	< 0.0001	0.55
Cooked yield, %	101.56	101.33	101.74	101.15	0.18	0.35	0.02	0.16
Sliced wt, kg	6.11	5.96	6.45	5.61	0.07	0.15	< 0.0001	0.45
Slice Count	225.38	226.49	232.98	218.89	2.17	0.71	< 0.0001	0.06
Slice yield (Green), %	98.53	98.01	98.84	97.71	0.46	0.41	0.07	0.24
Slice yield (Cooked), %	97.03	96.72	97.16	96.58	0.42	0.59	0.32	0.47

Table 3.13. Main effects of sire line and sex on cured sliced belly characteristics

	Sire line		Sex			*P* - values		
Item	EB5	P26	Barrows	Gilts	SEM	Sire line	Sex	Sire Line × Sex
Pens, n	40	36	36	40				
Blade Slice								
Length, cm	24.01	24.01	24.17	23.84	0.19	0.99	0.13	0.31
Width, cm	4.06	3.91	4.18	3.80	0.05	0.04	< 0.001	0.25
Total Slice Area, cm^2	94.15	90.69	97.28	87.56	1.22	0.04	< 0.001	0.07
Primary Lean Area, cm^2	35.79	37.92	37.31	36.40	1.45	0.16	0.54	0.32
Secondary Lean Area, cm^2	6.87	6.94	6.53	7.28	0.69	0.93	0.43	0.17
Middle Slice								
Length, cm	24.23	24.27	24.23	24.27	0.15	0.82	0.87	0.02
Width, cm	3.51	3.46	3.58	3.39	0.05	0.39	< 0.01	0.04
Total Slice Area, cm^2	88.45	86.10	91.00	83.55	1.21	0.15	< 0.001	0.08
Primary Lean Area, cm^2	23.65	24.73	23.80	24.57	0.59	0.35	0.19	0.02
Secondary Lean Area, cm^2	13.99	14.35	14.17	14.17	0.36	1.00	0.46	0.46
Flank Slice								
Length, cm	23.00	22.98	22.89	23.08	0.30	0.94	0.50	0.49
Width, cm	4.00	3.98	4.02	3.96	0.06	0.44	0.80	0.77
Total Slice Area, cm^2	91.61	90.55	91.67	90.50	1.61	0.57	0.53	0.57
Primary Lean Area, cm^2	29.89	31.00	29.77	31.13	0.77	0.30	0.20	0.44
Secondary Lean Area, cm^2	16.17	18.31	17.57	16.91	0.62	0.01	0.44	0.86
Average Slice[1]								
Length, cm	23.74	23.75	23.77	23.73	0.18	0.97	0.85	0.11
Width, cm	3.86	3.78	3.93	3.71	0.04	0.15	< 0.01	0.13
Total Slice Area, cm^2	91.41	89.11	93.31	87.20	1.18	0.14	< 0.01	0.13
Primary Lean Area, cm^2	21.36	22.48	21.91	21.93	0.61	0.08	0.96	0.06
Secondary Lean Area, cm^2	12.34	13.20	12.76	12.79	0.41	0.13	0.96	0.28
Percentage of Lean, %	36.98	40.25	37.25	39.99	0.94	< 0.001	< 0.001	0.12
Percentage of Fat, %	53.75	49.91	53.75	49.91	1.10	< 0.001	< 0.001	0.16
Lean : Fat	0.70	0.83	0.70	0.83	0.04	< 0.001	< 0.001	0.09

[1]Average slice image analysis was the mean of the image analysis evaluated on blade end, middle, and flank end slices.

Table 3.14. Interaction means of carcass characteristics, cutability, and loin and chop quality between sire line and sex

	EB5		P26			*P*-values		
Item	Barrow	Gilt	Barrow	Gilt	SEM	Sire Line	Sex	Sire line × Sex
Phase 1 ADFI, kg/d	2.09[a]	1.97[b]	2.18[a]	1.91[b]	0.09	0.69	< 0.001	0.03
Canadian Back, kg	3.58[b]	3.40[c]	3.79[a]	3.78[a]	0.06	< 0.001	0.03	0.05
Canadian back % chilled side wt	6.96[c]	7.21[b]	7.27[b]	7.96[a]	0.09	< 0.001	< 0.001	0.01
Boneless loin, kg	4.88[b]	4.65[c]	5.13[a]	5.14[a]	0.07	< 0.001	0.05	0.04
Boneless loin % chilled side wt	9.48[c]	9.86[b]	9.85[b]	10.83[a]	0.12	< 0.001	< 0.001	0.01
Boneless carcass cutting yield, %	52.21[c]	53.14[b]	53.37[b]	55.36[a]	0.24	< 0.001	< 0.001	0.02
Aged ventral b*	7.67[c]	7.63[c]	8.88[a]	7.84[bc]	0.27	0.01	0.03	0.05
Belly trim loss, %	13.96[bc]	14.56[b]	13.54[c]	15.52[a]	0.34	< 0.001	0.32	0.01
Middle slice length, cm	24.47[a]	23.98[b]	24.00[ab]	24.55[a]	0.23	0.87	0.82	0.02
Middle slice width, cm	3.68[a]	3.35[b]	3.49[b]	3.43[b]	0.07	< 0.01	0.39	0.04
Middle slice primary lean, cm^2	24.24[ab]	23.06[b]	23.38[b]	26.09[a]	0.88	0.35	0.19	0.02

[a–b]Within a row, least squares means lacking a common superscript differ ($P \leq 0.05$).

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CHAPTER 4: EFFECT OF DUROC SIRE LINES (BLINDED) ON EARLY AND AGED PORK QUALITY

ABSTRACT

Over the past 20 years, the industry has shifted from paying pig producers on a live weight basis to paying on a lean percent of carcass basis. This has strengthened the importance of developing genetic lines that increase growth performance while still improving pork quality. Today, Duroc terminal sires are often used in swine production because they can efficiently execute both of these intentions. The objective of this study was to compare pigs from a P26 Duroc sire line and a competitor sire line in order to determine how the P26 sire line matches with competitors in industry. Early and aged loin quality characteristics were evaluated in addition to early ham and belly quality characteristics. Pigs (*n*=320) were sourced from 2 different sire lines of Duroc ancestry. Red and green colors represented either a P26 Duroc or a competitor Duroc sire. A Red and Green sire line each provided 160 barrows and gilts. The MIXED procedure of SAS was used to evaluate the fixed effects of sire line, sex, and the interaction between sire line and sex, and effects were considered significant at $P<0.05$. Red sired pigs had heavier ($P<0.001$) birth (1.55 vs. 1.36 kg), weaning (6.46 vs. 5.85 kg), and allocation weights (23.74 vs. 22.65 kg). Overall (d0-98), average daily gain (**ADG**) was increased ($P<0.001$) by 0.07 kg/d in Green sired pigs as compared to Red sired pigs. Red sired pigs were leaner ($P\leq0.01$) at both the tenth and last rib by 0.19 and 0.25 cm, respectively. Red sired pigs had an increased ($P<0.01$) standardized fat free lean (**FFL**) by 1.31% units. Green sired pigs had increased ($P\leq0.01$) early ventral visual marbling (2.51 vs. 2.08 units), early chop visual marbling (2.61 vs. 2.31 units), early chop a* (8.95 vs. 8.32 units), and extractable lipid (3.31 vs. 2.84%). Early ventral visual color, instrumental color (L*, a*, and b*), and pH did not

differ ($P \geq 0.08$) between sire lines. Green sired pigs had increased ($P \leq 0.01$) aged ventral visual marbling (2.78 vs. 2.30 units), aged chop visual marbling (2.65 vs. 2.29 units), and aged chop subjective firmness (3.19 vs. 3.04 units). Aged ventral visual color, aged ventral instrumental color (L*, a*, and b*), aged ventral pH, and instrumental tenderness did not differ ($P \geq 0.16$) between sire lines. Green sired pigs had increased ($P < 0.001$) belly thickness by 0.38 cm and belly flop by 4.01 cm. Ultimately, Red sired pigs had heavier early weights and were leaner whereas Green sired pigs had faster growth rates and improved pork quality characteristics.

INTRODUCTION

Nearly 35 years ago, hogs were sold on a live weight basis (Hayenga et al., 1985); however, over time, incentive-based marketing systems have been introduced to the industry making lean percent of carcasses even more valuable (Schwab et al., 2007). Producers and packers have been working together to deliver leaner products to the consumer for the last 20 years (Chen et al, 2002). One way to accomplish this is through the development of superior genetics. Duroc pigs are often selected as terminal sires in U.S. swine production as they increase growth rate and performance and enhance meat quality (NPPC, 1995). Duroc terminal sires typically have increased visual color, visual marbling, and subjective firmness for early and aged ventral loins and chops when compared to other breeds (Edwards et al., 2003; Lowell et al., 2019). Duroc sired pigs also have improved belly quality as they have increased belly thickness and belly flop indicating thicker and firmer bellies (Lowell et al., 2019). The objective of this study was to compare pigs from either a P26 Duroc sire line or a competitor sire line in order to determine how the P26 sire line matched to competitors in industry. Early and aged loin quality characteristics were evaluated in addition to early ham and belly quality characteristics.

MATERIALS AND METHODS

Pig Background

Pigs (320 total) from 2 different sire lines of Duroc ancestry were used in the trial. Personnel of this trial were fully blinded to pig ancestry therefore genetic lines were represented by colors (Red and Green). Red and green colors represented either a P26 Duroc (Choice Genetics, West Des Moines, IA) or a competitor Duroc sire. The first sire line (Red) provided 160 barrows and gilts. The second sire line (Green) provided 160 barrows and gilts. All pigs were housed in pens (1.18m^2/pig) of 4 pigs of the same sex and sire line. Block 1 consisted of 60 Red sired pigs (28 barrows and 32 gilts) and 100 Green sired pigs (44 barrows and 56 gilts). Block 2 consisted of 100 Red sired pigs (52 barrows and 48 gilts) and 60 Green sired pigs (36 barrows and 24 gilts). A total of 40 pens were used in block 1 (7 barrow and 8 gilt pens from Red sires, and 11 barrow and 14 gilt pens from Green sires). A total of 40 pens were used in block 2 (13 barrow and 12 gilt pens from Red sires, and 9 barrow and 6 gilt pens from Green sires. Discrepancies in pen numbers were due to pig availability within each farrowing group. All other pig background information was similar to chapter 2.

A 3-phase, 98 d feeding program was used similar to chapter 3. Diet composition was identical to the diet described in chapter 2. On d 98, the heaviest pig from each pen (80 total pigs) was removed and transported to the University of Illinois Meat Science Laboratory (Urbana, IL) for slaughter on d 99. Also on d 99, the second heaviest and lightest pigs from each pen (160 total pigs) were removed and transported to a commercial scale federally inspected abattoir. The remaining pig (third heaviest) was slaughtered at the University of Illinois Meat Science Laboratory on d 101.

Harvest Procedures and Carcass Fabrication

For pigs harvested at the University of Illinois Meat Science Laboratory, all procedures followed chapter 2, however, last rib back fat was also measured in the determined location of the last rib. Harvest procedures for the federally inspected abattoir and carcass fabrication procedures mimicked chapter 2.

Early Quality Evaluation

Early loin quality and early ham quality evaluation procedures followed those outlined in chapter 2. Early belly quality evaluation procedures followed chapters 2 and 3.

Aged Postmortem Loin Quality Evaluation

Aged loin quality evaluation procedures followed those outlined in chapter 2, however, four chops from each loin were removed for further evaluations. Chop 1 was used to determine moisture and extractable lipid. Chop 2 was used to determine cook loss (%) and WBSF. Chop 3 was used for trained sensory panels. Chop 4 was saved and used as a backup sample.

Cook Loss, Warner-Bratzler Shear Force, & Loin Proximate Composition

Cook loss, WBSF, and loin proximate composition followed the procedures outlined in chapter 2.

Statistical Analysis

Data were analyzed using the MIXED procedure, similar to chapter 2, with pen (80 total) serving as the experimental unit.

RESULTS

Growth Performance, Carcass Characteristics, and Cutability

Birth weight, weaning weight, and allocation weight were increased ($P \leq 0.01$) in Red sired pigs by 0.19, 0.61, and 1.09 kg, respectively (Table 4.1). During phase 1 (d0-35), ADG, average daily feed intake (**ADFI**), and gain to feed (**G:F**) did not differ (*P*≥0.08) between sire lines. Green gilts had an increased G:F during phase 1 by 0.02 units compared to Red sired pigs as indicated by a sire line by sex interaction (*P*=0.02). During phase 2 (d36-70), ADG was increased by 0.09 kg/d and ADFI was increased by 0.19 kg/d in Green sired pigs (*P*<0.001). During phase 3 (d71-98), ADG and ADFI was increased (*P*<0.001) by 0.10 and 0.27 kg/d in Green sired pigs. Overall ADG and ADFI was increased (*P*<0.001) by 0.07 and 0.17 kg/d in Green sired pigs. Phase 2, 3, and overall G:F did not differ (*P*≥0.11) between sire lines.

Of the first and third heaviest pig in each pen, Green sired pigs had increased (*P*<0.001) ELW and HCW, by 5.1 and 4.76 kg (Table 4.2). Green sired pigs had increased (*P*<0.01) carcass yield (78.98 vs. 78.40%) and last rib back fat depth (2.78 vs. 2.53 cm). Red gilts had the lowest carcass yield by 0.72% indicated by a sire line by sex interaction (*P*=0.03). Tenth-rib back fat was increased (*P*=0.01) in Green sired pigs by 0.19 cm. Standardized fat-free lean was increased (*P*<0.01) in Red sired pigs by 1.31% units. LEA did not differ (*P*=1.00) between sire lines. Of the second and fourth heaviest pig in each pen, HCW did not differ (*P*=0.10) between sire lines. Last rib back fat was increased (*P*<0.01) by 0.37 cm in Green sired pigs; therefore, increasing (*P*<0.01) FFL by 1.66% units in Red sired pigs.

The cutability of each primal and of the carcass overall are displayed in table 4.3 (shoulder), 4.4 (loin), 4.5 (ham), 4.6 (belly and other cuts), 4.7 (overall). Green sired pigs had heavier (*P*≤0.04) whole shoulders by 0.27 kg, bone-in picnics by 0.24 kg, boneless picnics by 0.16 kg, and jowls by 0.05 kg. Percent of chilled side weight for whole shoulders was increased (*P*≤0.02) by 0.68%, bone-in Boston butts by 0.43%, boneless Boston butts by 0.40%, neckbones by 0.13%, and boneless shoulder by 0.50% in Red sired pigs. Bone-in Boston butt, boneless Boston butt, neckbone, clear plate, and boneless shoulder weights did not differ (*P*≥0.07) between sire lines. Green sired pigs had heavier whole loins (12.78 vs. 12.21 kg; $P<0.01$), trimmed loins (10.42 vs. 10.11 kg; $P=0.02$), and backribs (0.82 vs. 0.78 kg; $P<0.01$). Percent of chilled side weight was increased ($P\leq0.01$) for trimmed loins by 0.43%, Canadian backs by 0.41%, tenderloins by 0.07%, sirloins by 0.11%, backbones by 0.21%, and boneless loins by 0.58%. Red gilts had the highest percent of chilled side weight for backbones by 0.26% as indicated by a sire line by sex interaction ($P=0.01$). Canadian back, tenderloin, sirloin, backbone, and boneless loin weights did not differ ($P\geq0.41$) between sire lines.

Whole hams were heavier ($P\leq0.05$) by 0.61 kg, trimmed hams by 0.44 kg, inside hams by 0.14 kg, outside hams by 0.08 kg, knuckles by 0.04 kg, inner shanks by 0.06 kg, and boneless hams by 0.29 kg in Green sired pigs. A sire line by sex interaction indicated Green barrows had the heaviest whole hams ($P<0.001$) by 0.36 kg. A sire line by sex interaction ($P<0.001$) indicated both Green and Red barrows had heavier trimmed hams by 0.11 kg and Green barrows and Green gilts had heavier inner shanks by 0.02 kg. Red gilts had the lightest knuckles by 0.08 kg and boneless hams by 0.44 kg as indicated by a sire line by sex interaction ($P=0.04$). Lite butts were heavier ($P<0.01$) by 0.02 kg in Red sired pigs. A sire line by sex interaction ($P<0.01$) indicated Green barrows had the heaviest lite butts by 0.03 kg. Percent of chilled side weight for outside hams (5.43 vs. 5.31%; $P=0.05$) and lite butts (0.62 vs. 0.55%; $P<0.001$) was increased in Red sired pigs. Green barrows had the lowest percent of chilled side for lite butts by 0.12% as indicated by a sire line by sex interaction ($P=0.01$). Percent of chilled side weight for inner shanks was increased ($P=0.01$) by 0.05% in Green sired pigs.

Natural fall belly weight and percent of chilled side weight for natural belly weight was increased ($P<0.001$) by 0.66 kg and 0.68% in Green sired pigs. Percent of chilled side weight for spareribs was increased ($P<0.001$) by 0.17% in Red sired pigs. Sparerib weight did not differ

(*P*=0.84) between sire lines. Leaf fat and front and back foot weight was increased (*P*<0.01) by 0.10 kg and 0.08 kg in Green sired pigs. Percent of chilled side weight for leaf fat was increased (*P*=0.01) by 0.16% in Green sired pigs. Standardized trim weight did not differ (*P*=0.96) between sire lines.

Red sired pigs had an increased (*P*<0.01) bone-in lean cutting yield by 1.07% and an increased (*P*=0.02) boneless carcass cutting yield by 0.54%. Bone-in carcass cutting yield did not differ (*P*=0.08) between sire lines.

Pork Quality

Early ventral visual marbling was increased (2.51 vs. 2.08 units; *P*<0.001) in Green sired pigs (Table 4.8). Green barrows had the highest amount of early ventral visual marbling by 0.37 units as indicated by a sire line by sex interaction (*P*=0.04). Early ventral visual color, subjective firmness, L*, a*, b*, and pH did not differ (*P*≥0.08) between sire lines. Green sired pigs had increased early chop visual marbling (2.61 vs. 2.31 units; *P*=0.01), chop a* (8.95 vs. 8.32 units; *P*=0.01), and extractable lipid percentage (3.31 vs. 2.84%; *P*<0.01). Green barrows had increased (*P*=0.05) early chop subjective firmness by 0.16 units as indicated by a sire line by sex interaction (*P*=0.05). Early chop visual color, subjective firmness, L*, b* and moisture did not differ (*P*≥0.07) between sire lines.

Aged ventral visual marbling was greater (*P*<0.001) in Green sired pigs as compared to Red sired pigs by 0.48 units (Table 4.9). Aged ventral visual color, subjective firmness, L*, a*, b*, purge loss, and pH did not differ (*P*≥0.16) between sire lines. Green sired pigs had increased (*P*<0.01) aged chop visual marbling (2.65 vs. 2.29 units) and chop subjective firmness (3.19 vs. 3.04 units) compared to Red sired pigs. Aged chop visual color, L*, a*, b*, WBSF, and cook loss did not differ (*P*≥0.09) between sire lines.

Green sired pigs had increased (P<0.001) belly thickness (3.97 vs. 3.59 cm) and belly flop (19.64 vs. 15.63 cm) compared to Red sired pigs (Table 4.10)**.** Belly length and width did not differ (P≥0.91) between sire lines. Fresh ham visual color, L*, a*, b*, and pH did not differ (P≥0.28) between sire lines.

DISCUSSION

Market trends in the pork industry have changed over time such as any industry. More specifically, the industry has shifted from paying producers for pig ELW to a lean percentage based off carcass FFL (Hayenga et al., 1985; Schwab et al., 2007). Because of this shift in industry, the importance of selecting terminal sire lines that can enhance both growth performance and pork quality parameters are of value. Duroc pigs are often chosen as terminal sires in commercial swine crossbreeding scenarios as they improve fresh pork quality and increase growth rates and performance (Lowell et al., 2018, NPPC, 1995). Various traits including ADG, back fat, lean yield, pH, cook loss, and intramuscular fat are heritable traits in Duroc sired pigs (Cabling et al., 2015). Thus, the objective of this study was to compare pigs from either a P26 Duroc sire line or a competitor sire line in order to determine how the P26 sire line matched to competitors in industry. Early and aged loin quality characteristics were evaluated as well as fresh ham and belly quality characteristics.

While Red sired pigs started out at heavier early weights (birth, weaning, and allocation), Green sired pigs had increased ADG ultimately finishing at heavier ELW. Although there were differences in ADG, there were no differences amongst G:F between the two sire lines. Additionally, Green sired pigs had heavier carcasses therefore, they had an increased overall carcass yield. Red sired pigs were leaner at both the tenth and last rib; consequently, they had increased FFL. Additionally, Red sired pigs had a greater bone-in lean cutting yield and boneless carcass cutting yield by approximately 1% and 0.50%, respectively. Therefore, in terms of growth performance, Green sired pigs were superior to Red sired pigs. While Green sired pigs had heavier carcasses and greater carcass yields, Red sired pigs had leaner carcasses with increased FFL. However, the magnitude of difference in back fat was rather small. Red sired pigs held the advantage over Green sired pigs in terms of carcass cutability.

In terms of loin quality, Green sired pigs had heavier marbled loins at both 1 d and 14 d postmortem. Additionally, Green sired pigs had heavier marbled and redder aged chops with increased extractable lipid at 1 d postmortem. Green sired pigs also had heavier marbled and firmer aged chops. However, both early and aged visual color and instrumental color scores did not differ between the two sire lines. Additionally, there were no differences observed in ultimate pH, instrumental tenderness, or cook loss values. In terms of fresh belly characteristics, Green sired pigs had thicker and firmer bellies as belly thickness and belly flop values were increased for that sire line. Furthermore, in regards to fresh ham quality characteristics, there were no differences observed between the two sire lines. Therefore, Green sired pigs were superior in pork quality as compared to Red sired pigs. However, while statistically not different, Red sired pigs were considered acceptable for both ultimate pH and instrumental tenderness.

CONCLUSIONS

Duroc sired pigs have historically possessed better pork quality than other breeds and more recently have improved growth performance compared to previous years. In this study, pigs from either a P26 Duroc sire line or a competitor sire line were compared in order to evaluate how the P26 sire matched to competitors in industry. Overall, Green sired pigs had increased ADG, ELW, and carcass yields, but Red sired pigs were leaner thus, were superior in regards to FFL. Additionally, Red sired pigs held the advantage regarding carcass cutability. However, overall, Green sired pigs were superior in terms of both pork quality and belly quality.

TABLES

Table 4.1. Main effects of sire line and sex on growth characteristics

	Sire line		Sex			*P*-values		
Item	Green	Red	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	40	40	40				
Birth wt, kg	1.36	1.55	1.50	1.41	0.09	< 0.001	0.01	0.51
Weaning wt, kg	5.85	6.46	6.25	6.07	0.10	< 0.001	0.11	0.23
Allocation wt, kg	22.65	23.74	23.29	23.10	0.24	< 0.01	0.58	0.65
Phase 1 (d0-35)[1]								
BW d0, kg	24.67	25.75	25.33	25.08	0.34	< 0.01	0.45	0.86
ADG, kg/d	0.93	0.87	0.96	0.84	0.04	0.32	0.05	0.83
ADFI, kg/d	1.92	1.89	2.00	1.81	0.09	0.50	< 0.001	0.99
G:F	0.47	0.46	0.46	0.47	< 0.01	0.08	0.07	0.02
BW d35, kg	55.81	55.67	56.74	54.73	1.88	0.86	0.01	0.07
Phase 2 (d36-70)								
ADG, kg/d	1.12	1.03	1.14	1.01	0.01	< 0.001	< 0.001	0.87
ADFI, kg/d	3.14	2.95	3.22	2.87	0.11	< 0.001	< 0.001	0.91
G:F	0.36	0.35	0.35	0.35	0.01	0.11	0.93	0.60
BW d70, kg	95.03	91.68	96.56	90.16	1.58	< 0.01	< 0.001	0.14
Phase 3 (d71-98)								
ADG, kg/d	1.18	1.08	1.18	1.08	0.01	< 0.001	< 0.001	0.61
ADFI, kg/d	3.54	3.27	3.61	3.20	0.07	< 0.001	< 0.001	0.47
G:F	0.33	0.33	0.33	0.34	< 0.01	0.97	0.01	0.64
BW d98, kg	127.95	122.10	129.65	120.39	1.34	< 0.001	< 0.001	0.14
Overall (d0-98)								
ADG, kg/d	1.05	0.98	1.07	0.97	0.01	< 0.001	< 0.001	0.11
ADFI, kg/d	2.83	2.66	2.88	2.60	0.03	< 0.001	< 0.001	0.35
G:F	0.373	0.368	0.367	0.375	0.008	0.18	0.03	0.68

[1]Pigs were approximately 10 wks old on d0.

Table 4.2. Main effects of sire line and sex on carcass characteristics on pigs slaughtered at the University of Illinois Meat Science Laboratory

	Sire Line		Sex			*P*-values		
Item	Green	Red	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	40	40	40				
University of Illinois[1]								
Ending live weight, kg	125.67	120.57	127.52	118.71	1.42	< 0.001	< 0.001	0.20
HCW, kg[2]	99.29	94.53	100.59	93.23	1.28	< 0.001	< 0.001	0.10
Carcass yield, %	78.98	78.40	78.87	78.51	0.16	< 0.01	0.03	0.03
Loin muscle area, cm^2	45.09	45.09	44.95	45.23	1.57	1.00	0.72	0.35
10th rib back fat depth, cm	2.16	1.97	2.25	1.88	0.05	0.01	< 0.001	0.44
Last rib back fat depth, cm	2.78	2.53	2.84	2.47	0.15	< 0.01	< 0.001	0.26
Standardized fat-free lean, %[3]	50.02	51.33	49.64	51.71	1.21	< 0.01	< 0.001	0.56
Federally Inspected Abattoir[4]								
HCW, kg	90.99	88.66	90.69	88.96	1.65	0.10	0.22	0.51
Last rib back fat depth, cm	2.86	2.49	2.85	2.50	0.10	< 0.01	< 0.01	0.57
Standardized fat-free lean, %[5]	50.14	51.80	50.17	51.77	0.32	< 0.01	< 0.01	0.83

[1]Values are based on data collected from the first and third heaviest pig in each pen.

[2]HCW includes the left and right sides with leaf fat and standardized trim still intact.

[3]Standardized fat-free lean = ((8.588 + (0.465 x HCW, lb) - (21.896 x 10^{th} rib back fat depth, in) + (3.005 x LTL area, in^2)) ÷ HCW) x 100, (Burson and Berg, 2001).

[4]Values based on data collected from the second and fourth heaviest pig in each pen.

[5]Standardized fat-free lean = ((23.568 + (0.503 x HCW, lb) - (21.348 x last rib back fat thickness, in))÷HCW) x 100, (Burson and Berg, 2001).

Table 4.3. Main effects of sire line and sex on shoulder carcass cuts

	Sire Line		Sex			*P*-values		
Item	Green	Red	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	40	40	40				
Whole shoulder, kg	12.44	12.17	12.74	11.86	0.10	0.04	< 0.001	0.22
% chilled side wt	25.97	26.65	26.25	26.37	0.15	< 0.001	0.44	0.72
Bone-in Boston, kg	3.77	3.77	3.89	3.65	0.07	0.99	< 0.001	0.19
% chilled side wt	7.85	8.28	8.02	8.10	0.24	< 0.001	0.28	0.98
Bone-in picnic, kg	5.63	5.39	5.70	5.32	0.13	< 0.01	< 0.001	0.36
% chilled side wt	11.76	11.87	11.81	11.82	0.16	0.28	0.95	0.57
Boneless Boston, kg	3.46	3.46	3.57	3.35	0.07	0.97	< 0.001	0.17
% chilled side wt	7.21	7.61	7.37	7.44	0.23	< 0.001	0.27	0.93
Boneless picnic, kg	4.05	3.89	4.12	3.82	0.11	< 0.01	< 0.001	0.42
% chilled side wt	8.43	8.54	8.49	8.48	0.14	0.13	0.80	0.44
Neckbones, kg	0.93	0.94	0.95	0.93	0.02	0.65	0.38	0.98
% chilled side wt	1.94	2.07	1.95	2.06	0.04	0.02	0.03	0.38
Jowl, kg	1.34	1.29	1.37	1.26	0.05	0.04	< 0.001	0.06
% chilled side wt	2.79	2.82	2.81	2.80	0.07	0.54	0.81	0.21
Clear plate, kg	0.78	0.74	0.81	0.71	0.03	0.07	< 0.001	0.90
% chilled side wt	1.61	1.62	1.67	1.57	0.09	0.80	< 0.01	0.51
Boneless shoulder, kg[1]	7.50	7.37	7.70	7.17	0.06	0.12	< 0.001	0.24
% chilled side wt	15.64	16.14	15.86	15.92	0.11	< 0.001	0.56	0.66

[1]Boneless shoulder = boneless Boston butt (NAMP # 406A), kg + boneless picnic (NAMP #405A), kg.

Table 4.4. Main effects of sire line and sex on loin carcass cuts

	Sire Line		Sex			*P*-values		
Item	Green	Red	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	40	40	40				
Whole loin, kg	12.78	12.21	13.03	11.96	0.14	< 0.01	< 0.001	0.43
% chilled side wt	26.65	26.69	26.80	26.54	0.11	0.81	0.10	0.41
Trimmed loin, kg	10.42	10.11	10.54	9.99	0.09	0.02	< 0.001	0.38
% chilled side wt	21.73	22.16	21.70	22.18	0.19	< 0.01	< 0.01	0.39
Canadian Back, kg	3.53	3.54	3.60	3.47	0.05	0.85	0.02	0.15
% chilled side wt	7.36	7.77	7.42	7.71	0.06	< 0.001	< 0.01	0.78
Tenderloin, kg	0.45	0.46	0.46	0.44	0.01	0.41	0.01	0.38
% chilled side wt	0.94	1.01	0.96	0.99	0.04	< 0.001	0.02	0.66
Sirloin, kg	0.86	0.86	0.87	0.85	0.02	0.89	0.41	0.72
% chilled side wt	1.79	1.90	1.79	1.90	0.03	< 0.01	< 0.01	0.52
Backribs, kg	0.82	0.78	0.82	0.78	0.02	< 0.01	0.01	0.89
% chilled side wt	1.72	1.71	1.69	1.74	0.02	0.64	0.03	0.30
Backbone, kg	1.80	1.80	1.84	1.76	0.10	0.99	0.01	0.20
% chilled side wt	3.75	3.96	3.80	3.92	0.25	< 0.01	0.03	0.01
Boneless loin, kg[1]	4.84	4.86	4.93	4.77	0.07	0.73	0.02	0.19
% chilled side wt	10.09	10.67	10.16	10.60	0.07	< 0.001	< 0.001	1.00

[1]Boneless loin = Canadian back loin (NAMP #414), kg + tenderloin (NAMP #415A), kg + sirloin (NAMP #413D), kg.

Table 4.5. Main effects of sire line and sex on ham carcass cuts

	Sire Line		Sex			*P*-values		
Item	Green	Red	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	40	40	40				
Whole ham, kg	11.67	11.06	11.70	11.04	0.21	< 0.001	< 0.001	0.03
% chilled side wt	24.33	24.26	24.09	24.49	0.17	0.56	< 0.01	0.19
Trimmed ham, kg	10.01	9.57	10.06	9.51	0.19	< 0.001	< 0.001	0.03
% chilled side wt	20.86	21.00	20.73	21.12	0.18	0.35	0.01	0.27
Inside ham, kg	1.88	1.74	1.85	1.77	0.07	< 0.001	< 0.01	0.32
% chilled side wt	3.92	3.82	3.82	3.92	0.11	0.06	0.03	0.97
Outside ham, kg	2.55	2.47	2.57	2.45	0.04	0.05	< 0.01	0.19
% chilled side wt	5.31	5.43	5.30	5.44	0.05	0.05	0.03	0.87
Knuckle, kg	1.39	1.35	1.39	1.36	0.02	0.03	0.12	0.04
% chilled side wt	2.91	2.96	2.85	3.02	0.02	0.15	< 0.001	0.27
Inner shank, kg	0.74	0.68	0.73	0.69	0.03	< 0.001	< 0.01	0.05
% chilled side wt	1.55	1.50	1.51	1.54	0.04	0.01	0.11	0.23
Lite butt, kg	0.26	0.28	0.27	0.27	0.01	< 0.01	0.77	< 0.01
% chilled side wt	0.55	0.62	0.56	0.61	0.02	< 0.001	0.01	0.01
Boneless ham, kg[1]	6.82	6.53	6.81	6.54	0.16	< 0.01	< 0.01	0.04
% chilled side wt	14.22	14.34	14.04	14.52	0.18	0.41	< 0.01	0.40

[1]Boneless ham = inside ham (NAMP #402F), kg + outside ham (NAMP #402E), kg + knuckle (NAMP #402H), kg + lite butt, kg+ inner shank, kg.

Table 4.6. Main effects of sire line and sex on belly and miscellaneous cuts

	Sire Line		Sex			*P*-values		
Item	Green	Red	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	40	40	40				
Natural fall belly, kg	7.17	6.51	7.08	6.60	0.12	< 0.001	< 0.001	0.15
% chilled side wt	14.94	14.26	14.57	14.63	0.09	< 0.001	0.63	0.54
Spareribs, kg	1.73	1.73	1.78	1.67	0.01	0.84	< 0.001	0.32
% chilled side wt	3.61	3.78	3.68	3.72	0.04	< 0.001	0.27	0.70
Miscellaneous Cuts								
Standardized trim, kg	0.16	0.16	0.19	0.13	0.01	0.96	< 0.01	0.38
% chilled side wt	0.34	0.35	0.39	0.30	0.02	0.46	< 0.01	0.48
Leaf fat, kg	0.80	0.70	0.85	0.64	0.02	< 0.01	< 0.001	0.59
% chilled side wt	1.66	1.50	1.75	1.41	0.04	0.01	< 0.001	0.73
Front and back foot, kg	1.12	1.04	1.11	1.05	0.01	< 0.01	0.01	0.60
% chilled side wt	2.33	2.29	2.28	2.34	0.03	0.29	0.09	0.67

Table 4.7. Main effects of sire line and sex on carcass cutability

	Sire Line		Sex			*P*-values		
Item	Green	Red	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	40	40	40				
Bone-in carcass cutting yield, %[1]	77.17	77.56	76.86	77.87	0.15	0.08	< 0.001	0.87
Bone-in lean cutting yield, %[2]	62.25	63.32	62.33	63.24	0.20	< 0.01	< 0.01	0.97
Boneless carcass cutting yield, %[3]	54.88	55.42	54.64	55.67	0.15	0.02	< 0.001	0.52

[1]Bone-in carcass cutting yield = [(trimmed ham, kg + bone-in Boston, kg + bone-in picnic, kg + trimmed loin, kg + natural fall belly, kg) ÷ left side chilled weight, kg] x 100.

[2]Bone-in lean cutting yield = [(trimmed ham, kg + bone-in Boston, kg + bone-in picnic, kg + trimmed loin, kg) ÷ left side chilled weight, kg] x 100.

[3]Boneless carcass cutting yield = [(inside ham, kg + outside ham, kg + knuckle, kg, + lite butt, kg + inner shank, kg) + (Canadian back loin, kg + tenderloin, kg + sirloin, kg) + (boneless Boston, kg + boneless picnic, kg) + (belly, kg)) ÷ left side chilled weight] x 100.

Table 4.8. Main effects of sire line and sex on early loin and chop face quality and color[1]

	Sire Line		Sex			*P*-values		
Item	Green	Red	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	40	40	40				
Loin								
Visual color[2]	3.51	3.58	3.60	3.49	0.08	0.43	0.22	0.49
Visual marbling[2]	2.51	2.08	2.39	2.20	0.10	< 0.001	0.04	0.04
Subjective firmness[3]	3.26	3.19	3.24	3.21	0.06	0.16	0.54	0.30
Lightness, L*[4]	52.06	53.34	52.14	53.26	1.67	0.08	0.11	0.42
Redness, a*[4]	9.22	9.30	9.19	9.33	0.41	0.83	0.66	0.41
Yellowness, b*[4]	7.56	7.71	7.48	7.78	0.54	0.60	0.27	0.69
Ventral pH	5.56	5.57	5.58	5.55	0.03	0.55	< 0.01	0.55
Chop								
Visual color	3.69	3.71	3.79	3.61	0.10	0.76	0.03	0.25
Visual marbling	2.61	2.31	2.64	2.28	0.08	0.01	< 0.01	0.12
Subjective firmness	2.83	2.72	2.80	2.75	0.21	0.07	0.35	0.05
Lightness, L*	55.60	56.01	55.33	56.29	0.79	0.52	0.12	0.32
Redness, a*	8.95	8.32	8.75	8.52	0.27	0.01	0.36	0.98
Yellowness, b*	7.60	7.19	7.39	7.40	0.53	0.13	0.97	0.39
Moisture, %	73.31	73.55	73.22	73.64	0.24	0.09	< 0.01	0.82
Extractable Lipid, %	3.31	2.84	3.31	2.84	0.09	< 0.01	< 0.01	0.93

[1]Early postmortem traits were evaluated 1 d postmortem

[2]NPPC color based on the 1999 standards measured in half point increments where 1 = palest, 6 = darkest and where 1 = least amount of marbling, 6 = greatest amount of marbling.

[3]NPPC firmness based on the 1991 scale measured in half point increments where 1 = softest, 5 = firmest.

[4]L* measures darkness (0) to lightness (100; greater L* indicates a lighter color), a* measures redness (greater a* indicates a redder color), b* measures yellowness (greater b* indicates a more yellow color).

Table 4.9. Main effects of sire line and sex on aged loin and chop quality[1]

	Sire Line		Sex			*P*-values		
Item	Green	Red	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	40	40	40				
Loin								
Visual color[2]	3.62	3.48	3.60	3.49	0.10	0.16	0.27	0.80
Visual marbling[2]	2.78	2.30	2.66	2.43	0.12	< 0.001	0.03	0.58
Subjective firmness[4]	3.14	3.08	3.16	3.06	0.07	0.20	0.04	0.10
Lightness, L*[5]	52.28	52.05	51.65	52.69	0.39	0.68	0.07	0.50
Redness, a*[5]	8.27	8.17	8.29	8.16	0.30	0.61	0.48	0.73
Yellowness, b*[5]	6.91	6.81	6.77	6.95	0.85	0.69	0.45	0.94
Purge loss, %	4.32	4.26	4.02	4.56	0.35	0.90	0.28	0.90
Ventral pH	5.57	5.57	5.59	5.56	0.02	0.95	0.02	0.69
Chop								
Visual color	3.48	3.45	3.56	3.37	0.09	0.75	0.02	0.88
Visual marbling	2.65	2.29	2.66	2.28	0.09	< 0.01	< 0.01	0.57
Subjective firmness	3.19	3.04	3.13	3.11	0.03	< 0.01	0.59	0.18
Lightness, L*	54.02	53.72	53.35	54.39	0.76	0.63	0.08	0.32
Redness, a*	8.76	8.36	8.62	8.51	0.31	0.09	0.63	0.07
Yellowness, b*	7.48	7.13	7.23	7.38	0.52	0.15	0.51	0.22
Warner-Bratzler shear force, kg[9]	2.63	2.71	2.71	2.64	0.05	0.30	0.33	0.47
Cook Loss, %	20.60	20.83	20.94	20.49	0.40	0.68	0.42	0.20

[1]Early postmortem traits were evaluated 1 d postmortem
[2]NPPC color based on the 1999 standards measured in half point increments where 1 = palest, 6 = darkest and where 1 = least amount of marbling, 6 = greatest amount of marbling.
[4]NPPC firmness based on the 1991 scale measured in half point increments where 1 = softest, 5 = firmest.
[5]L* measures darkness (0) to lightness (100; greater L* indicates a lighter color), a* measures redness (greater a* indicates a redder color), b* measures yellowness (greater b* indicates a more yellow color).

Table 4.10. Main effects of sire line and sex on fresh belly characteristics

	Sire Line		Sex			*P*-values		
Item	Green	Red	Barrows	Gilts	SEM	Sire Line	Sex	Sire line × Sex
Pens, n	40	40	40	40				
Belly								
Length, cm	69.71	69.67	70.30	69.07	0.31	0.92	0.01	0.61
Width, cm	24.59	24.62	24.71	24.49	0.17	0.91	0.34	0.13
Thickness, cm[1]	3.97	3.59	3.95	3.60	0.04	< 0.001	< 0.001	0.46
Flop, cm	19.64	15.63	18.82	16.45	1.16	< 0.001	0.01	0.39
Ham								
Visual color[2]	3.11	3.05	3.10	3.06	0.10	0.65	0.78	0.65
Lightness, L*[3]	57.40	56.85	57.26	56.99	0.55	0.48	0.74	0.50
Redness, a*[3]	10.45	10.54	10.41	10.57	0.47	0.80	0.65	0.83
Yellowness, b*[3]	8.41	8.36	8.41	8.36	0.26	0.90	0.91	0.59
Ham pH	5.75	5.73	5.75	5.73	0.04	0.28	0.31	0.09

[1]Thickness was an average of measurements from 8 locations from the anterior to posterior.

[2]Visual ham color was based on 4 point visual scale where 1=darkest and 4=lightest.

[3]L* measures darkness (0) to lightness (100; greater L* indicates a lighter color), a* measures redness (greater a* indicates a redder color), b* measures yellowness (greater b* indicates a more yellow color).L* measures darkness (0) to lightness (100; greater L* indicates a lighter color).

Table 4.11. Interaction means of carcass characteristics, cutability, and loin and chop quality between sire line and sex

	Green		Red			*P*-values		
Item	Barrow	Gilt	Barrow	Gilt	SEM	Sire Line	Sex	Sire line × Sex
Pens, n								
Phase 1 Gain : Feed	0.46[b]	0.48[a]	0.46[b]	0.46[b]	0.01	0.08	0.07	0.02
MSL carcass yield %	78.99[a]	78.97[a]	78.76[a]	78.04[b]	0.20	< 0.01	0.03	0.03
Whole ham, kg	11.88[a]	11.47[b]	11.52[b]	10.61[c]	0.23	< 0.001	< 0.001	0.03
Trimmed ham, kg	10.17[a]	9.85[b]	9.96[ab]	9.18[c]	0.21	< 0.001	< 0.001	0.03
Knuckle, kg	1.39[a]	1.40[a]	1.39[a]	1.31[b]	0.02	0.03	0.12	0.04
Inner shank, kg	0.75[a]	0.73[ab]	0.71[b]	0.65[c]	0.03	< 0.001	< 0.01	0.05
Lite butt, kg	0.30[a]	0.27[b]	0.27[c]	0.25[b]	0.01	< 0.01	0.77	< 0.01
Lite butt, % chilled side wt	0.50[b]	0.59[a]	0.62[a]	0.62[a]	0.02	< 0.001	0.01	0.01
Boneless ham, kg	6.88[a]	6.77[a]	6.75[a]	6.31[b]	0.17	< 0.01	< 0.01	0.04
Backbone, % chilled side wt	3.77[b]	3.74[b]	3.83[b]	4.09[a]	0.26	< 0.01	0.03	0.01
Early ventral visual marbling	2.69[a]	2.32[b]	2.08[bc]	2.08[c]	0.12	< 0.001	0.04	0.04
Early chop subjective firmness	2.91[a]	2.74[b]	2.69[b]	2.75[b]	0.21	0.07	0.35	0.05

[a–c]Within a row, least squares means lacking a common superscript differ ($P \leq 0.05$).

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CHAPTER 5: EFFECT OF VARYING GROWTH RATES ON EARLY AND AGED PORK LOIN AND CHOP QUALITY

ABSTRACT

The pork industry has observed an upward trend in ending live weights, resulting in heavier hot carcass weights (**HCW**). Heavier HCW positively influences loin tenderness; however, the mechanism of this effect is unclear. One possibility is increased growth rate, associated with greater HCW, resulting in more tender loins. The objective was to determine the effect of growth rate on early and aged pork quality. Pigs (*n*=634) were divided into three groups based on average daily gain (kg/d) from 12-26wk of age; slow (< 0.96kg/d, *n*=96), intermediate (0.96-1.16kg/d, *n*=452), and fast (≥ 1.17kg/d, *n*=86). The MIXED procedure of SAS was used to evaluate the main effects of growth rate, breed, sex, and their interactions on loin quality. Birth and weaning weight did not differ between growth rate ($P \geq 0.15$) but, overall ADG was increased ($P < 0.001$) in fast growing pigs by 0.15 kg/d. Bone-in lean cutting yield decreased ($P < 0.001$) as growth rate increased meaning slow growing pigs had the highest yield by 1.46%. Early ventral subjective firmness was slightly increased ($P = 0.03$) in intermediate growing pigs by 0.21 units compared to slow growing pigs. Early ventral and chop visual color, marbling, and instrumental color (L*, a*, and b*) did not differ between growth rates ($P \geq 0.13$). Aged ventral visual color was increased ($P = 0.03$) in fast and intermediate growing pigs by 0.23 units. Intermediate growing pigs had firmer loins ($P = 0.04$) by 0.07 units. Ventral a* increased as growth rate increased ($P = 0.04$) indicating fast growing pigs had the reddest loins (9.77 vs. 9.26 vs. 8.99 units). Aged ventral marbling, ultimate pH, purge loss, cook loss, instrumental tenderness, chop moisture, and extractable lipid did not differ ($P \geq 0.32$) between growth rate groups. Both ELW and HCW increased as growth increased, but Duroc-sired pigs were heavier than Pietrain-sired

pigs in the slow growth rate category. Between all growth rate groups, slow growing Pietrain-sired pigs had the smallest loin eye areas (**LEA**). While faster growth rates improved aged ventral visual color, instrumental tenderness did not differ between growth rate groups.

INTRODUCTION

Over the last few years, the packing industry has been witnessing changes in swine ending live weights (**ELW**) ultimately affecting HCW. From 1995 to 2019, pork HCW have increased from 82 kg to 96.5 kg (USDA, 2019). Currently, it is expected that this trend will continue over the next few years. Previous studies have determined that as carcasses are becoming heavier, chops are becoming more tender (Harsh et al., 2017; Price et al., 2019). However, the mechanism underlying these effects is still unclear. What has been relatively established is that as carcasses become heavier it can be attributed to heavier pigs at birth and weaning in addition to increased average daily gain (**ADG**) or growth rate. On average, light weight pigs took 10-14 days longer to reach market weight and had reduced overall ADG when compared to heavy weight pigs of the same age (Mahan & Lepine, 1991).

Previously, the mechanism behind slow growth rates in pigs was evaluated. It was determined that when comparing slow, average, and fast growing pigs, body weight in pigs is consistently increased in fast growing pigs from birth to 170 days of age (He et al., 2016). Additionally, this study determined that fast growing pigs consistently had increased ADG from birth throughout the final phases of finishing and heavier carcasses when compared to average and slow growing pigs. This could suggest that birth and weaning weights and growth rates of pigs are possibly related. It was also reported that fast growing pigs had more back fat and larger loin eye areas in comparison to average and slow growing pigs; however, this study did not evaluate the effects of growth rate on pork quality (He et al., 2016). A separate study evaluated low birth weights in pigs and its effect on meat tenderness and ultimately determined that light weight pigs had paler colored (early L*) and less tender loins when compared to heavy weight pigs of the same age (Gondret et al., 2006). Therefore, the objective of this study was to evaluate the effect of varying growth rates on early and aged pork quality. Based upon past studies, which determined heavy carcasses improved chop tenderness, it was hypothesized that pigs belonging to the fastest growth rate group would have more tender loin chops.

MATERIALS AND METHODS

Protocols used during the live phase portion of the experiment were approved by the Institutional Animal Care and Use Committee at the University of Illinois.

Pig Background

Pigs (634 total) were from either Pietrain or Duroc ancestry (Choice Genetics, West Des Moines, IA). Pigs were raised in 4 separate groups at the University of Illinois Swine Research Center over a time period of 2.5 years. Group 1 consisted of 80 Duroc and 80 Pietrain pigs, Group 2 consisted of 162 Pietrain pigs, and Groups 3, and 4, consisted of 152, and 160, Duroc pigs, respectively. All pigs were housed in pens of the same sex and sire line. Groups 1, 3, and 4 consisted of 4 pigs per pen and group 2 consisted of 3 pigs per pen. The discrepancy in total pigs per pen is due to number of available pigs sire line per group. Within groups, pigs were raised in blocks, approximately 2 weeks apart, based on farrowing dates. All pigs were fed the same diets as outlined in chapter 2. Day 0 was considered the beginning of the feeding trial and pigs (10 weeks of age) were weighed to determine beginning weight. Pigs were raised in a 3-phase rotational program and weighed at the end of each of the 3 feeding phases (d 35, 70, & 91/98). Daily feed allotments were recorded and data were summarized to calculate ADG, average daily feed intake (**ADFI**), and gain to feed (**G:F**). ADG was calculated on an individual pig basis whereas ADFI and G:F were calculated by pen. Overall ADG of each pig was calculated in order to split pigs into slow, intermediate, and fast growth rate groups (Figure 5.1). The standard deviation of the mean was used to determine the intermediate growth rate group, one standard deviation below the mean was the slow growth rate group, and one standard deviation above the mean was the fast growth rate group.

Due to a scheduling conflict, block 1 of group 2 was harvested on d 91 and block 2 of group 2 was harvested on d 98. Groups 1, 3, and 4 were all harvested on d 98. Depending on the group, d 91 or d 98 was considered the end of the feeding portion of the trial and all pigs were weighed in order to calculate overall ADG, ADFI, and G:F. For groups 1, 3, and 4 the heaviest pig from each pen was removed on d 98 and transported to the University of Illinois Meat Science Laboratory (Urbana, IL) for slaughter on d 99. Also on d 99, the second heaviest and lightest pigs from each pen were removed and transported to a commercial scale federally inspected abattoir. The remaining pig was slaughtered at the University of Illinois Meat Science Laboratory on d 101. For group 2, the heaviest pig from each pen was transported to the University of Illinois Meat Science Laboratory on d 91 and d 98 to be harvested on d 92 and d 99. Also on d 92 and d 99 the second heaviest pig from each pen was removed and transported to a commercial scale, federally inspected abattoir to be harvested. On d 93 and d 100, the lightest pig in each pen was transported to the University of Illinois Meat Science Laboratory to be harvested on d 94 and d 101.

Harvest Procedures and Carcass Fabrication

Harvest procedures for the federally inspected abattoir and the University of Illinois Meat Science Laboratory follow those outlined in chapter 2. Carcass fabrication procedures also followed those outlined in chapter 2.

Loin Quality Evaluation

Early and aged postmortem quality procedures followed those outlined in chapter 2. For all groups, chop 1 was used to determine early quality measurements and proximate composition. Chop 2 was used to determine cook loss (%) and Warner-Bratzler Shear Force (**WBSF**). Proximate composition, cook loss, and WBSF procedures follow those outlined in chapter 2.

Statistical Analysis

Within the population, pigs were divided into three groups based on ADG, reported in kg/d, from 12-26wk of age; slow (< 0.96kg/d, *n*= 96), intermediate (0.96-1.16kg/d, *n*= 452), and fast (≥ 1.17kg/d, *n*= 86). The standard deviation of the mean of ADG was calculated in order to categorize the intermediate growth rate group. Slow growing pigs were considered one standard deviation below the mean and fast growing pigs were considered one standard deviation above the mean. Data were analyzed using the MIXED procedure of SAS (SAS Inst. In., Cary, NC) as a three-way ANOVA (rate × breed × sex) with trial as a random variable. Pig (634 total) served as the experimental unit. Main effect of rate, breed, sex, and their interactions on growth performance, cutability, and pork quality characteristics were considered significant at $P<0.05$. Least squares means were separated using a probability of difference (PDIFF) statement in the MIXED procedure of SAS. Normality of residuals was tested using the UNIVARIATE procedure of SAS. Homogeneity of variances was tested using the Levene's hovtest option in the GLM procedure of SAS.

RESULTS

Distribution of Sex and Breed within ADG category

The depiction of pigs distributed per growth rate category is represented in Figure 5.1 and Table 5.1. As expected, the majority of pigs fell within the intermediate growth rate category (*n*=452). The slow growth rate group had 96 pigs and the fast growth rate group had 86 pigs. The slow growth rate group had more gilts (*n*=85) as compared to the fast growth rate group (*n*=12). The fast growth rate group had more barrows (*n*=74) as compared to the slow growth rate group (*n*=11). The slow growth rate group had slightly more Durocs than Pietrains (57 vs. 39 pigs).

Growth Performance

Birth weight did not differ between rate, sex, or breed ($P \geq 0.06$; Table 5.2). Weaning weight was increased by 0.69 kg ($P < 0.01$) in Duroc pigs compared with Pietrain pigs, but weaning weight did not differ between rate or sex. Overall ADG was different ($P < 0.001$) between growth rate groups with fast growing pigs having the highest overall ADG (1.21 vs. 1.06 vs. 0.89 kg/d). There was a rate by sex interaction ($P < 0.01$) for overall ADG (Figure 5.2). Overall ADG was not different between barrows and gilts in both the slow and fast growth rate groups. In the intermediate growth rate group, barrows had an increased overall ADG by 0.04 kg/d compared to intermediate gilts.

Carcass Cutability

Bone-in lean cutting yield decreased ($P < 0.001$) as growth rate increased thus, slow growing pigs had the greatest yield by 1.46% (Table 5.3). Gilts had an increased ($P \leq 0.01$) bone-in carcass cutting yield by 1.67%, bone-in lean cutting yield by 1.11%, and boneless carcass cutting yield by 1.56% compared to barrows. Pietrain sired pigs had an increased ($P \leq 0.02$) bone-in carcass cutting yield (75.65 vs. 74.22%), bone-in lean cutting yield (61.15 vs. 60.03%), and boneless carcass cutting yield (53.42 vs. 52.46%) compared to Duroc sired pigs. All three-way interactions for carcass cutability characteristics were not significant (*P*≥0.06).

Carcass Characteristics

There was a rate by breed interaction for both ELW and HCW (*P*<0.01**;** Table 5.6). Both ELW and HCW increased as growth rate increased, but within the slow growth rate groups Duroc-sired pigs had heavier ELW and HCW by 7.21 kg and 6.72 kg compared to Pietrain-sired pigs. There was also a rate by breed interaction (*P*=0.05) for LEA. In the intermediate and fast growth rate groups, LEA of Duroc and Pietrain pigs were not different from each other, but within the slow growth rate group Duroc-sired pigs had larger LEA by 4.08 cm^2. In general, as growth rate increased, ELW, HCW, tenth rib back fat, and LEA all increased (*P*<0.001; data not shown) indicating fast growing pigs had heavier ELW by 10.96 kg and HCW by 8.46 kg as well as more tenth rib back fat by 0.18 cm and larger LEA by 2.32 cm. Barrows had increased (*P*≤0.01) ELW, HCW, and tenth rib back fat by 3.17 kg, 2.99 kg, and 0.28 cm, respectively, compared to gilts (data not shown). Duroc sired pigs had heavier HCW (101.01 vs. 98.62 kg; *P*=0.04) and increased tenth rib back fat (2.10 vs. 1.75 cm; *P*<0.001) compared to Pietrain sired pigs (data not shown).

Early Loin and Chop Quality

There was a rate by breed interaction (*P*=0.02) for early ventral visual marbling; within each growth rate group Duroc pigs had more marbling than Pietrain pigs. However, within the slow and fast growth rate group, the magnitude of difference between breeds was much larger than the intermediate growth rate group (slow = 0.77 units, intermediate = 0.34 units, fast = 0.77 units; data not shown). There was a rate by sex interaction (*P*=0.02) for early chop L*. Within the slow and fast growth rate groups, gilts had decreased L* values compared to barrows, but in the intermediate growth rate group gilts had increased L* values compared to barrows (data not shown). There was a breed by sex interaction (*P*=0.05) for early chop visual color. Within the Duroc breed, barrows had darker chops (0.09 units) compared to gilts, but within the Pietrain breed, gilts had darker chops (0.19 units) compared to barrows (data not shown). There was a rate by breed by sex interaction (*P*<0.01) for early ventral visual marbling (data not shown). In the intermediate and fast growth rate groups, Duroc and Pietrain barrows had heavier marbled loins (0.16; 0.39; 0.22; 0.08 units, respectively) compared to gilts. Within the slow growth rate group, Duroc barrows also had heavier marbled loins by 0.87 units compared to gilts, but within the Pietrain breed, gilts had heavier marbled loins by 0.23 units compared to barrows. For each of these interactions, the differences between sex or breed within a growth rate category was minimal.

Early ventral subjective firmness was increased (*P*=0.03) in intermediate growing pigs by 0.21 units compared to slow growing pigs; slow and fast growing pigs were not different from each other (Table 5.4). Barrows had increased (*P*≤0.02) early ventral visual marbling (2.22 vs. 1.97 units), ultimate ventral pH (5.62 vs. 5.59 units), chop visual marbling (2.49 vs. 2.25 units), and extractable lipid (3.30 vs. 2.74%) compared to gilts. Gilts had increased (*P*<0.01) chop moisture by 0.50% compared to barrows. Duroc pigs had increased (*P*≤0.02) early ventral visual marbling (2.40 vs. 1.78 units), ultimate ventral pH (5.62 vs. 5.58 units), chop visual marbling (2.69 vs. 2.06 units), and extractable lipid (3.38 vs. 2.66%) compared to Pietrain pigs. Pietrain pigs had increased (*P*<0.01) chop moisture by 0.72% compared to Duroc pigs.

Aged Loin and Chop Quality

Aged loins from intermediate and fast growing pigs were subjectively darker (*P*≤0.05) than those of slow growing pigs by 0.23 units (Table 5.5). Aged ventral visual marbling was increased (P<0.01) by 0.35 units in barrows as compared to gilts and increased in Duroc-sired pigs by 0.39 units as compared to Pietrain-sired pigs. Aged ventral subjective firmness was increased (P=0.04) in the intermediate growth rate group by 0.20 units. Loins from fast growing pigs were more red (P≤0.05) by 0.51 units than those of intermediate or slow growing pigs, but L* and b* did not differ (P≥0.42) by rate. Aged ventral pH, purge loss, cook loss, and WBSF did not differ (P≥0.09) between rate, sex, or breed.

DISCUSSION

Over the last 25 years, pork HCW have increased by approximately 18% (USDA, 2019). Previous studies have determined that loin chops from heavier carcasses are more tender than those from lighter carcasses (Harsh et al., 2017; Price et al., 2019), however, the mechanism of this change remains unclear. It is possible that heavier carcasses are derived from pigs with increased growth rates compared to their contemporaries. Therefore, it was hypothesized that fast growing pigs in the present study would yield both heavier carcasses and more tender loin chops as compared to intermediate and slow growing pigs.

In the present study, birth and weaning weight did not differ between growth rate groups; therefore, differences in ELW can be attributed solely to differences in ADG. Given the origin of these pigs was a series of sire line comparisons where pigs were allotted to treatment in an effort to minimize weight differences at the initiation of the trials (10 weeks of age), the lack of difference in birth and weaning weights is not as surprising. Others have noted that faster growing pigs did have increased birth and weaning weights (He et al., 2016). Ending live weights of pigs from the fast growing group were 11 kg heavier than intermediate and 26 kg heavier than slow-growing pigs. These differences persisted in HCW with the fast-growing group being 8 kg heavier than the intermediate and 20 kg heavier than the slow-growing group.

Additionally, fast-growing pigs were fatter and had larger LEA compared to the slower-growing groups. In a recent review regarding heavier weight pigs, it was reported that as market pigs increase in weight by 10 kg, it is expected that back fat will increase by 0.18 cm (Wu et al., 2017). Within the present study, as pigs increased in weight by approximately 9 kg, back fat increased by approximately 0.18 cm. The increase in LEA of the fast-growing group in the present study is 1.73 cm^2 less in magnitude to previous reports (He et al., 2016).

Based off passed literature, it was hypothesized that chops from the fast growth rate pigs would be more tender than chops from intermediate and slow growing pigs. Using regression equations from past studies (Harsh et al., 2017; Price et al., 2019), it was determined that when cooked to 71˚ C, fast growing pigs would have SSF values of 12.91 and 11.52 when compared to slow growing pigs, which would have SSF values of 15.51 and 12.90. Additionally, both of these studies determined, as carcasses get heavier, cook loss deceases. Based upon a recent study, it could be concluded that as carcasses get heavier, loins will be darker at early and aged time points (Harsh et al., 2017). This study also concluded that at 20 d postmortem, heavier carcasses yielded heavier marbled aged loins. On the contrary, a separate study did not see any differences in color or marbling as carcasses got heavier at 1 d postmortem (Price et al., 2019).

Within the present study, there were no differences in WBSF or cook loss amongst growth rate groups. The carcasses used within this study were chilled at approximately 4˚ C for 24 therefore, they were not blast chilled per normal industry settings. It is interesting to speculate the method used to chill carcasses could have attributed to the lack of difference in instrumental tenderness values. Carcasses of varying weights (light vs. heavy) chill at different rates such that it has become a concern in terms of pork quality (Overholt et al., 2019). Furthermore, the lack of difference in instrumental tenderness values could be attributed to the number of observations within each growth rate category. However, this was an opportunistic study such that data from previous studies was utilized.

In terms of pork quality, intermediate growing pigs had slightly firmer loins as compared to slow growing pigs at early and aged time points; however, the slow and fast growing pigs were not different from each other. Additionally, fast and intermediate growing pigs had darker aged loins as subjective visual color scores were increased, but instrumental L* did not differ between growth rate groups. Fast growing pigs also had slightly redder aged loins as compared to intermediate and slow growing pigs. Overall, ultimate pH did not differ between the growth rate groups at 1 or 14 d postmortem. Although quality differences were observed, any differences in early and aged loin quality were minimal.

CONCLUSION

From reports of heavier weight carcasses in the literature, it was expected fast growing pigs would have more tender chops, but ultimately, growth rate did not alter tenderness in the present population of Duroc- and Pietrain-sired pigs. Therefore, the hypothesis that growth rate contributes to differences in tenderness between light and heavy carcasses is not supported. Additionally, intermediate and fast growing pigs had slightly darker loins and fast growing pigs had slightly more red loins, but the observed differences in pork quality characteristics were minimal.

FIGURES

Figure 5.1. The depiction of pigs represented within each growth rate category as determined by overall ADG.

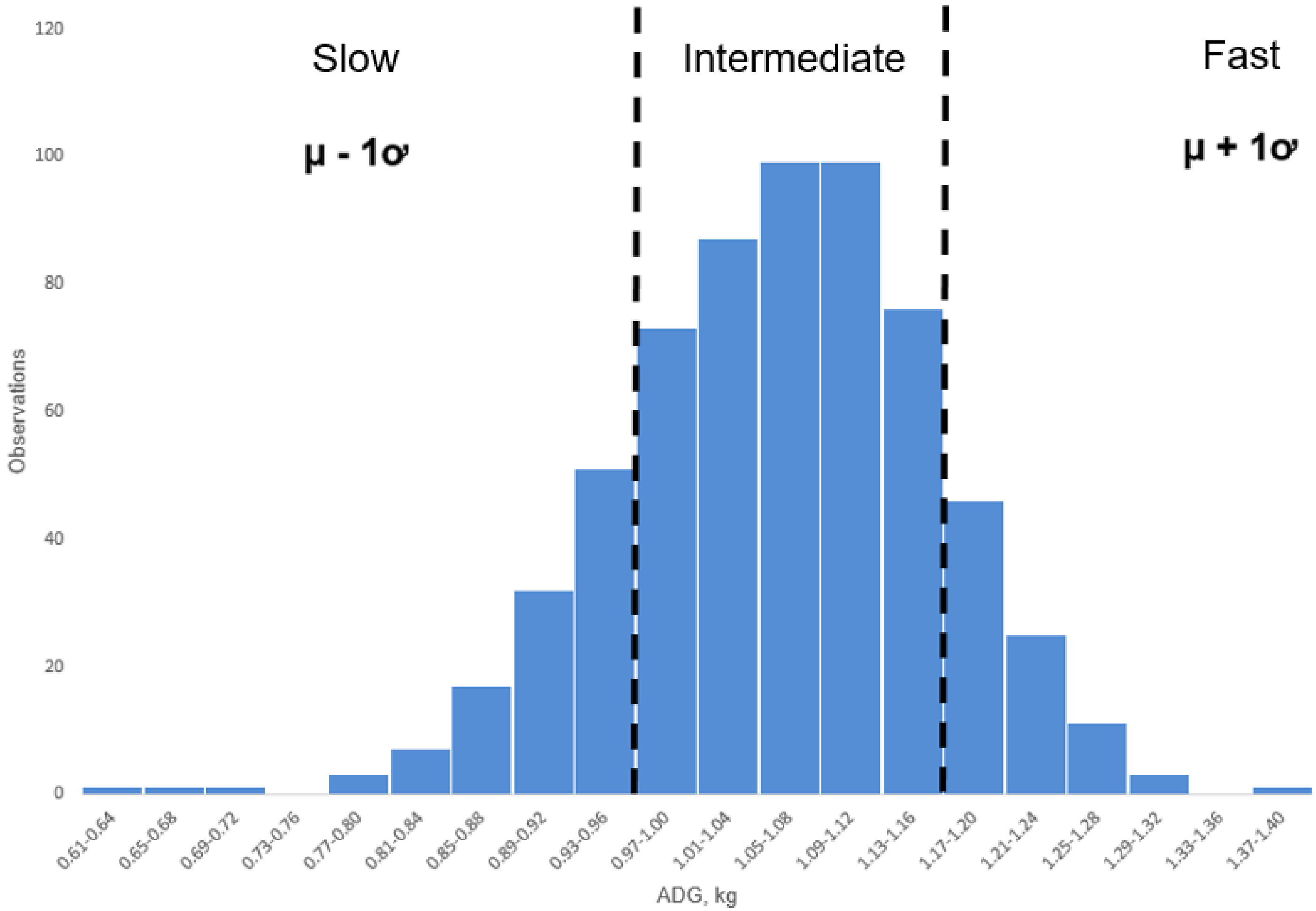
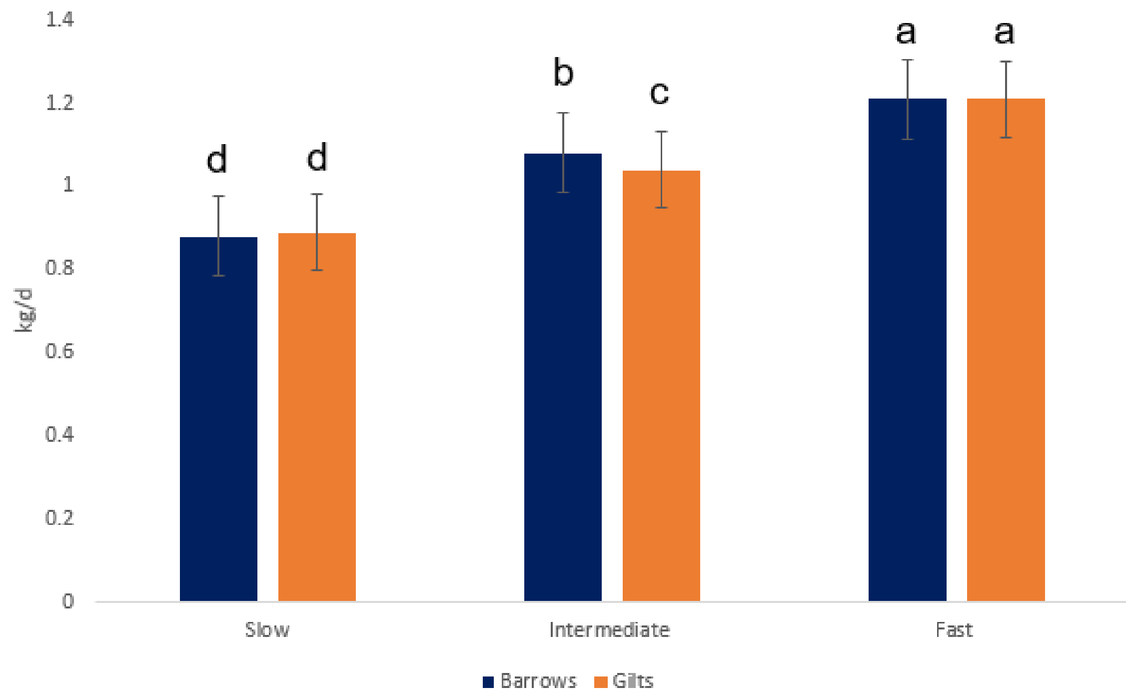


Figure 5.2. Effect of rate and sex on overall ADG whereas least square means lacking a common superscript differ ($P \leq 0.05$).



TABLES

Table 5.1. Number of pigs per rate, breed, and sex

	Slow		Intermediate		Fast	
Item	Durocs	Pietrains	Durocs	Pietrains	Durocs	Pietrains
Barrows	5	6	149	77	38	36
Gilts	52	33	140	86	8	4

Table 5.2. Main effects of rate, breed, and sex on growth performance

	Rate			Sex		Breed			*P*-value[1]		
Item	Slow	Intermediate	Fast	Barrows	Gilts	Pietrain	Duroc	SEM	Rate	Sex	Breed
Birth weight, kg	1.51	1.59	1.65	1.63	1.54	1.55	1.62	1.65	0.15	0.06	0.29
Wean weight, kg	6.44	6.38	6.40	6.54	6.27	6.06	6.75	0.32	0.95	0.12	< 0.01
Overall ADG	0.89[c]	1.06[b]	1.21[a]	1.06	1.05	1.05	1.05	< 0.01	< 0.001	0.12	0.73

[a–c]Within a row, least squares means of rate lacking a common superscript differ ($P \leq 0.05$).

[1]All interactions were not significant ($P \geq 0.13$) except Rate x Sex interaction for overall ADG. See Figure 5.2.

Table 5.3. Main effects of rate, breed, and sex on carcass cutability

	Rate			Sex		Breed			*P*-value[1]		
Item	Slow	Intermediate	Fast	Barrows	Gilts	Pietrain	Duroc	SEM	Rate	Sex	Breed
Bone-in carcass cutting yield, %[2]	75.33	74.93	74.55	74.10	75.77	75.65	74.22	1.43	0.37	< 0.001	< 0.01
Bone-in lean cutting yield, %[3]	61.88[a]	60.42[b]	59.45[c]	60.03	61.14	61.15	60.03	1.40	< 0.001	< 0.01	0.02
Boneless carcass cutting yield, %[4]	53.18	53.00	52.65	52.16	53.72	53.42	52.46	1.15	0.43	< 0.001	0.01

[a–c]Within a row, least squares means of rate lacking a common superscript differ ($P \leq 0.05$).

[1]Interactions were not significant ($P \geq 0.06$)

[2]Bone-in carcass cutting yield = [(trimmed ham, kg + bone-in Boston, kg + bone-in picnic, kg + trimmed loin, kg + natural fall belly, kg) ÷ left side chilled weight, kg] x 100.

[3]Bone-in lean cutting yield = [(trimmed ham, kg + bone-in Boston, kg + bone-in picnic, kg + trimmed loin, kg) ÷ left side chilled weight, kg] x 100.

[4]Boneless carcass cutting yield = [(inside ham, kg + outside ham, kg + knuckle, kg, + lite butt, kg + inner shank, kg) + (Canadian back loin, kg + tenderloin, kg + sirloin, kg) + (boneless Boston, kg + boneless picnic, kg) + (belly, kg)) ÷ left side chilled weight] x 100.

Table 5.4. Main effects of rate, breed, and sex on early postmortem loin and chop quality[1]

	Rate			Sex		Breed			*P*-value[6]		
Item	Slow	Intermediate	Fast	Barrows	Gilts	Pietrain	Duroc	SEM	Rate	Sex	Breed
Loin											
Visual color[2]	3.50	3.55	3.49	3.56	3.47	3.49	3.53	0.11	0.76	0.28	0.71
Visual marbling[3]	2.18	2.04	2.05	2.22	1.97	1.78	2.40	0.10	0.42	0.01	< 0.001
Subjective firmness[4]	3.21[b]	3.42[a]	3.29[ab]	3.29	3.32	3.32	3.30	0.14	0.03	0.72	0.85
Lightness, L*[5]	51.23	50.75	51.01	51.04	50.95	51.07	50.93	1.14	0.69	0.87	0.85
Redness, a*[5]	9.36	9.75	10.01	9.64	9.78	9.86	9.55	0.33	0.32	0.65	0.36
Yellowness, b*[5]	6.54	6.74	6.86	6.72	6.71	6.94	6.48	1.17	0.72	0.98	0.20
Ventral pH	5.60	5.61	5.60	5.62	5.59	5.58	5.62	0.04	0.80	0.02	0.02
Chop											
Visual color	3.38	3.51	3.59	3.47	3.52	3.47	3.52	0.15	0.13	0.48	0.56
Visual marbling	2.27	2.36	2.49	2.49	2.25	2.06	2.69	0.12	0.36	0.02	< 0.001
Subjective firmness	2.90	3.02	2.99	2.98	2.96	2.90	3.04	0.18	0.48	0.84	0.22
Lightness, L*	54.88	54.33	55.08	55.39	54.13	55.11	54.41	1.73	0.47	0.06	0.42
Redness, a*	8.60	9.12	8.93	8.97	8.81	9.04	8.73	0.33	0.16	0.53	0.32
Yellowness, b*	6.24	6.41	6.25	6.54	6.06	6.58	6.02	1.08	0.76	0.08	0.12
Moisture, %	73.35	73.12	73.22	72.98	73.48	73.52	72.93	0.25	0.32	< 0.01	< 0.01
Extractable lipid, %	2.95	2.99	3.11	3.30	2.74	2.66	3.38	0.25	0.72	< 0.01	< 0.01

[a–c]Within a row, least squares means of rate lacking a common superscript differ ($P \leq 0.05$).
[1] Early postmortem traits were evaluated 1 d postmortem
[2] NPPC color based on the 1999 standards measured in half point increments where 1 = palest, 6 = darkest.
[3] NPPC marbling based on the 1999 standards measured in half point increments where 1 = least amount of marbling, 6 = greatest amount of marbling
[4] NPPC firmness based on the 1991 scale measured in half point increments where 1 = softest, 5 = firmest
[5] L* measures darkness (0) to lightness (100; greater L* indicates a lighter color), a* measures redness (greater a* indicates a redder color), and b* measures yellowness (greater b* indicates a more yellow color).
[6] All interactions were not significant ($P \geq 0.11$) except loin visual marbling rate x breed ($P=0.02$) and rate x breed x sex ($P<0.01$), chop visual color ($P=0.05$), and chop L* ($P=0.02$)

Table 5.5. Main effects of rate, breed, and sex on aged postmortem loin and chop quality [1]

	Rate			Sex		Breed			*P*-value[6]		
Item	Slow	Intermediate	Fast	Barrows	Gilts	Pietrain	Duroc	SEM	Rate	Sex	Breed
Loin											
Visual color[2]	3.28^{b}	3.51^{a}	3.51^{a}	3.44	3.43	3.36	3.52	0.11	0.03	0.86	0.11
Visual marbling[3]	2.31	2.37	2.36	2.52	2.17	2.15	2.54	0.10	0.87	$<$ 0.01	$<$ 0.01
Subjective firmness[4]	3.23^{b}	3.43^{a}	3.36^{ab}	3.41	3.27	3.37	3.30	0.15	0.04	0.07	0.45
Lightness, L*[5]	52.93	52.32	52.81	52.76	52.61	53.07	52.30	1.08	0.42	0.77	0.26
Redness, a*[5]	8.99^{b}	9.26^{b}	9.77^{a}	9.35	9.33	9.19	9.49	0.54	0.04	0.92	0.28
Yellowness, b*[5]	7.05	7.13	7.28	7.18	7.12	7.27	7.03	0.84	0.83	0.81	0.50
Ventral pH	5.62	5.63	5.64	5.63	5.63	5.61	5.65	0.04	0.49	0.73	0.09
Purge loss, %	5.79	6.07	5.93	5.74	6.11	6.04	5.81	1.33	0.74	0.31	0.62
Chop											
Cook loss, %	19.09	18.55	18.65	18.57	18.95	18.21	19.31	1.18	0.63	0.48	0.11
WBSF, kg	2.62	2.55	2.61	2.54	2.64	2.54	2.65	0.11	0.51	0.13	0.18

[a–c]Within a row, least squares means of rate lacking a common superscript differ ($P \leq 0.05$).
[1] Early postmortem traits were evaluated 1 d postmortem
[2] NPPC color based on the 1999 standards measured in half point increments where 1 = palest, 6 = darkest.
[3] NPPC marbling based on the 1999 standards measured in half point increments where 1 = least amount of marbling, 6 = greatest amount of marbling
[4] NPPC firmness based on the 1991 scale measured in half point increments where 1 = softest, 5 = firmest
[5] L* measures darkness (0) to lightness (100; greater L* indicates a lighter color), a* measures redness (greater a* indicates a redder color), and b* measures yellowness (greater b* indicates a more yellow color).
[6] All interactions were not significant ($P \geq 0.07$)

Table 5.6. Rate by breed interaction effects

	Slow		Intermediate		Fast		
Item	Duroc	Pietrain	Duroc	Pietrain	Duroc	Pietrain	SEM
ELW, kg	117.11[c]	109.9[d]	127.56[b]	128.26[b]	138.81[a]	138.93[a]	2.32
HCW, kg	92.36[c]	85.64[d]	101.01[b]	100.96[b]	109.65[a]	109.25[a]	2.01
Carcass yield, %	78.53	77.99	78.92	78.84	78.83	78.97	0.72
LEA, cm	47.44[a]	43.36[b]	48.75[a]	49.02[a]	50.03[a]	52.38[a]	2.93
Tenth rib back fat, cm	1.90	1.39	2.15	1.81	2.25	2.06	0.15

Table 5.7. Rate by sex interaction effects

	Slow		Intermediate		Fast		
Item	Barrows	Gilts	Barrows	Gilts	Barrows	Gilts	SEM
Early chop L*	56.49[a]	53.26[b]	53.99[b]	54.67[a]	55.68[a]	54.47[b]	2.06

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