

THE EFFECTS OF SIRE LINE, SLAUGHTER WEIGHT, AND GENDER ON PORK
QUALITY AND YIELD CHARACTERISTICS

by

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(Under the Direction of T. DEAN PRINGLE)

ABSTRACT

Meat quality line (MQL) and lean yield line (LYL) sires were mated to commercial females to determine the effects of gender, sire line, and slaughter weight on carcass yield and quality characteristics. Differing slaughter weights of 113, 136, and 159 kg were randomly assigned to three pigs within a litter and gender category. Results indicate that LYL had consistent advantages in carcass yield and trimness. MQL had greater marbling and firmness in the longissimus dorsi. MQL had better overall quality, but due to the increased fat, had lower percentages of fat free lean (FFL). As slaughter weights increased, both fat and muscle increased, but FFL decreased and no quality differences were found. Barrows were consistently fatter and lighter muscled than gilts. Proximate analysis showed that MQL had higher fat content than LYL, but lower measured moisture levels.

INDEX WORDS: Pork Quality, Carcass Yield, Sire Line, Slaughter Weight

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DEDICATION

I would like to dedicate the body of work for the past two years to my family. My parents, Jim and Sue Moore, as well as my brother, Parker, have always encouraged and pushed me to pursue this graduate degree. My fiancé, Jaime, also helped make all of this possible through the past two years and has been a constant rock through the many projects.

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CHAPTER 1

INTRODUCTION

Pork continues to be a significant source of highly-valued animal protein for the growing global population. Pork consumption makes up approximately 50 percent of the world's daily meat protein intake (U.S. Pork Manual, Today's Pork Industry). Pork is not consumed in certain regions and certain populations of the world, however pork ranks first in per capita global meat consumption (Davis and Lin, 2005). Within the United States, pork ranks third in meat consumption, behind beef and chicken (Davis and Lin, 2005). With the amount of pork consumed in the world and United States, there is a demand from consumers for better quality pork, and also from producers for better yields. Pork consumption contributes high quality protein to a balanced diet as a result of expanding penetration into the foodservice marketplace and global demand, the demand of pork is rising. Due to the rise in the consumption of pork in the foodservice sector, emphasis is being placed on development of genetic lines that excel in pork quality attributes (i.e., color, marbling, firmness, palatability) compared to lean growth. Thus, the purpose of this study was to determine the effects of gender and slaughter weights on carcass quality attributes as well as carcass composition for both a lean yield and a meat quality sire line when mated to females, of similar genetics, from a commercial swine genetics company.

CHAPTER 2

LITERATURE REVIEW

According to the Study on the Pork Market Worldwide (Soare & Chiurciu, 2017), swine meat provided over 50% of the world-wide meat consumption. Because of the increase in pork consumption, the hot carcass weight (HCW) of U.S. pork carcasses has increased by 13 kg, representing an increase of more than 0.6 kg/year since 1995 (USDA NASS, 2017). Today, over 25% of the United States pork production is exported, representing 8.5 million tons of pork and pork products (Lowell et al., 2018). Pork products remain the most consumed animal proteins in the world as the United States continues to export to countries such as Mexico, Japan, and China where a demand continues to rise for U.S pork (U.S. Meat Export Federation, 2017).

Differences between Japanese and Mexican expectations in pork quality results in global demand for varying levels of pork quality. The Mexican consumers have a greater demand for lean pork (Ngapo et al., 2018). Conversely, the Japanese consumers and importers place an importance on attributes that relate to meat quality, such as color and marbling (Murphy et al., 2015). The U.S. producer is now tasked with producing a pork product that not only meets the differing demands for the export markets but also the demands of the domestic market. Overall, the demands of the U.S. consumer align more with the Mexican market which places an emphasis on leanness, however, pork utilization in the foodservice sector requires that pork quality is taken into account.

Over the past decades, the swine industry has moved from a live weight market-based system toward lean-based percentage pricing, which supplies the consumer with a leaner product (Chen et al., 2002). This leaner product has caused a reduction in eating quality for consumers (Moon et al. 2003; Newcom et al., 2005; Wiseman et al., 2007). Research has shown that improved pork quality results in a more tender, juicy, and overall more favorable product (Brewer et al., 2001). Due to the export market demand, breeding objectives in the U.S. swine industry are changing to address the desire for a higher quality, higher valued product. Even with these adjustments to selection pressure for lean growth in the industry, today's pork is leaner than pork produced in the early 2000's. The divergence in demand for pork is leading to development of selection programs designed to obtain the higher perceived meat quality while maintaining the lean value of a hog carcass.

THE IMPACT OF INCREASING SLAUGHTER WEIGHTS

Slaughter weights have been steadily increasing in the United States with an average of 112 kg for barrows and gilts in 1994 (Morgan et al., 1994). While there are potential advantages to this increase in slaughter weight, the limitation to increasing these weights is associated with reductions in growth rate and carcass lean percentage as slaughter weight increases and reductions in feed efficiency (Cisneros et al., 1996). Bertol et al. (2015) concluded that increasing slaughter weight increased the volume of meat but did not have a significant effect on the meat yield. With benefits to producer and packer profitability, the trend for heavier carcass weights is likely to continue (Harsh et al., 2017). Limitations in the ability of slaughter facilities to physically handle heavier carcasses may affect just how heavy live weights go; however, to date that tipping point

has not been met as evidence by the trend for increasing pork carcass weights (USDA NASS, 2019)

The effect of increasing slaughter weight on quality of pork products remains a question of interest to the U.S. swine industry. Weight of the whole loin or weights of individual cuts from the loin did not correlate with shear force according to Dilger et al. (2010). In the Pork Chain Quality Audit (Cannon et al., 1995), it was reported that although the slaughter weights were greater, there were inconsistent live weights. The average slaughter weight during this audit was 111.2 kg, which is close to the average (112 kg) determined by Morgan et al. (1994) in the Pork Chain Quality Audit: Pork Distribution Channel Audit Report. Research assessing the relationship between hot carcass weight and pork quality showed that the proportion of variability in loin and ham quality was poor and unpredictable (Harsh et al., 2017).

As slaughter weight increases, dressing percentage also increases. Albar et al. (1990) determined that for every 10 kg increased in slaughter weight, the dressing percentage also increased by 0.5 percentage units. Additionally, “the weight of the pooled primal cuts, subprimal cuts, and other cuts increased with slaughter weight” (Bertol et al., 2015). Slaughter weight did not, however, influence the drip loss. Bertol et al. (2015) reported that the increase in primal cut weights associated with increased carcass weight had little influence on meat yield, which validated the benefits of slaughtering heavier pigs. These results suggest that in the current lean-value marketing system, the heavier live animal should yield more product at a similar percentage of carcass yield.

One study showed that, “major problems identified with heavier slaughter weights include excessive fat, inadequate muscle-color/water holding capacity, inadequate

muscling, extreme cut-weight variation, and thin bellies” (Cannon et al., 1996). With these deficits, it directly impacts the market and the lost revenue for the producer. The belly quality and size has one of the largest influences on carcass revenue and is affected most by increasing slaughter weights. Thinner bellies do not slice as well in production and are not as uniform or visually appealing in the retail package.

COLOR

Since pork quality is associated with lean color measured 24 hours post-rigor (Kauffman et al., 1993), the change in muscle color tone at inconsistent live weights and heavier slaughter weights could pose an issue in the pork market. Muscle pH can also affect lean color as muscles with a lighter pink color generally have a lower pH (Warriss et al., 2007). Muscle fiber type can also affect the pH and color of muscles. The pH from muscles with higher red fiber content will tend to be higher pH, while a greater incidence of white fibers in the muscle leads to a lower pH (Warriss et al., 2007). Consumer purchase decisions are based on pork color, and recent research has found they prefer the dark reddish-pink options (Arkfield et al., 2017; United States Department of Agriculture, 2019).

The National Pork Producer’s Council use a scale from 1.0 – 6.0 to determine pork color (Grades of Meat, 2019). A 1.0 on the Pork Quality Standards Scale is pale pinkish-gray to white. A 6.0 on the scale is dark purplish red. Consumers typically prefer to purchase the 4.0 pork product which is a dark reddish pink. While consumers prefer choosing the dark reddish-pink color, darker-colored loins, with more marbling, are often selected for premium programs which typically involves the international marketplace

where there is a strong demand for high-quality products (Homer and Sutton, 2009; Lusk et al., 2017).

Although much of the quality-based sorting that occurs in packing plants is based on subjective color scores, a colorimeter can also be used as an objective tool for measuring meat color. The Hunter colorimeter is one objective tool that can be used, and measures light reflectance from the surface of the meat. These reflectance values can be used in the CIELAB color space to calculate values for L*, a*, and b* values (Bogdansky, F. M. 1975). Similar objective color value points from a Minolta colorimeter have been correlated to the NPPC color scales. An NPPC color score of 4.0 has a Minolta L* value of 43 (Berg et al., 2000). Different tissues transmit and reflect light differently. Depending on the reflection or transmission of the light by the meat product, the color is determined. As the surface of the meat moistens due to exudate, the light reflects giving it a paler appearance (Boler et al., 2010).

The meat of pigs slaughtered at heavier weights have shown more intense red color in comparison to meat from lighter weight pigs (Bertol et al., 2015). The increase in slaughter weight increased the color saturation, suggesting that with increased weight there was increased redness of meat. Argumentatively, the Pork Chain Quality Audit reported inadequate muscle-color/water-holding-capacity (Cannon et al., 1995). This audit also showed that 12.7% and 14.7% of the loins and the hams, respectively, contained two-toned muscle color (Cannon et al., 1995).

As HCW increases, loin color becomes darker and redder. Increased HCW also resulted in darker ham-face color and a redder semimembranosus muscle (Harsh et al., 2017). However, Correa et al. (2006) reported that slaughter weight had no direct

correlation with subjective color scores. Several studies determined that color differs based on location within the longissimus muscle (Van Oeckel and Warnants, 2003; Homm et al., 2006). The longissimus muscle from pigs slaughtered at a heavier weight (133 kg) was darker, redder, and had more myoglobin than the longissimus muscle of pigs slaughtered at 116 and 124 kg (Latorre et al., 2004). This is a more desirable color in Japanese import markets (Lowell et al., 2018), but producers are faced with the challenge of producing meat that meet the demands of the domestic consumer as well.

TENDERNESS

Not only can increasing slaughter weight directly affect the color of the product, but it also directly effects the tenderness, with a decrease in tenderness of the longissimus thoracis muscle associated with heavy weight carcasses. Additionally, increased slaughter weight showed an increase in shear force (Cisneros et al., 1996). This decline in tenderness may be due to “lower content of soluble collagen in the muscle as the animal ages (Bertol et al., 2015). In contrast to these findings, Harsh et al. (2017) found that heavier carcasses produced more tender loin chops as assessed by slice shear force (SSF).

Tenderness is one of the most important traits in determining pork quality for consumers. Management of this trait can be challenging due to the number of preharvest and postharvest influences. Not only does the tenderness change in the post-slaughter stages, but it also changes with postmortem storage (Dilger et al., 2010) and is initially influenced by the pigs breed type. Other postmortem factors also influence tenderness, including sarcomere length, collagen content, and postmortem proteolysis (Koochmaraiet et al., 2002). Sarcomere length changes during rigor, leaving a shorter length and less tender meat. Postmortem proteolysis reduces structural proteins, with an increase in

tenderness as the outcome. Koohmaraie (1994) believed that refrigeration temperatures are thought to be related to this protein degradation. Loins became more tender with an increase in postmortem storage (Dilger et al., 2010) between days 7 and 14. This makes categorizing carcasses or loins into tenderness groups a difficult task.

pH POSTMORTEM CHANGES

The term “quality”, in terms of meat, means many things to consumers. These attributes include pre-slaughter factors and go all the way to the consumer’s kitchen. When looking at quality as a whole, the loss of value reported per market hog slaughtered was estimated to be \$10.10, which is up to 10% of the overall animal value (Cannon et al., 1996). A more recent study showed the loss closer to \$8.00 per carcass (Stetzer and McKeith, 2003). Postmortem pork quality is typically determined by muscle color, texture, and structure and can be categorized as one of these three conditions: “Normal”; pale, soft, and exudative (PSE); and dark, firm and dry (DFD). These conditions are directly related to pH of the muscle that affects the quality of the meat. In a recent study in commercial pork packaging facilities where over 3500 carcasses were examined the longissimus pH ranged from 5.37 to 6.79 (King et al., 2017). If there is an elevated carcass temperature and rapid pH decline early postmortem, then the result is meat that is PSE or PSE-like. Conversely, if there is a slow pH decline and/or a glycogen deficiency in the muscle (usually from long term stress), then DFD meat is likely. Pale soft and exudative meat in pork is more common than DFD meat and has been a large topic of examination in the meat industry. According to a study by Cannon et al. (1996), an average of 10.2% of carcasses were PSE, compared to DFD carcasses with an average of 3.8% in the U.S. market. In a similar study, PSE and DFD meat combined was observed

in 26% of carcasses evaluated (Kauffman et al. 1993). Differences in the levels of these defects in these studies may be partially due to the number of carcasses evaluated and (or) geographic location of the plants evaluated.

Research has been conducted using 24-hour pH to better predict pork quality attributes such as color of lean, firmness, and water-holding capacity. Boler et al. (2008) reported that 24-h postmortem pH had the highest correlation with these pork quality attributes. Variation in pork quality across the industry has impacted the consumer acceptance of pork. This variability in quality attributes at the retail level could potentially make the industry less competitive with other animal protein products. Reduced variability in weight and quality of pork products would offer more value to the packer (Arkfield et al., 2016). Research focusing on increased slaughter weights suggest that the heavier pigs are more prone to developing pale, soft, and exudative conditions (Cisneros et al., 1995). Furthermore, heavier carcasses have produced loins that exhibit a lower pH value (King et al., 2017). This directly affects the quality of the carcass and retail cuts on the consumer's dinner plate. The larger a carcass is, the longer it takes for the temperature to decline, which can directly result in lowered pH and subsequent pork quality (King et al., 2017). Not only does carcass weight affect the pH and overall quality of pork, Overholt et al. (2016) showed that barrows had a higher pH than gilts at 24 hours.

INTRAMUSCULAR FAT

In addition to color, exudate, and firmness affecting pork quality, marbling has long been known as an influencer of pork quality and palatability. Research has shown that higher levels of marbling result in higher consumer ratings for tenderness, juiciness

and flavor (Brewer et al., 2001). According to Lowell et al., (2018), color and marbling are two of the main loin qualities that “influence customer acceptability of pork.” Furthermore, “Japanese importers prefer a darker more highly-marbled product, and Mexican importers prefer a high lean product” (Lowell et al., 2018). This poses a dilemma with U.S. pork production because of the pressure to meet both domestic and international demands for pork. Newcom et al. (1995) further confirmed that increased levels of loin intramuscular fat are associated with increased customer acceptance of the pork longissimus dorsi muscle.

Marbling score is directly related to the amount of intramuscular fat present in muscle. The Pork Chain Quality Audit presented by Cannon et al. (1996) determined that excessive fat in pork is a major concern in the industry. This excessive fat can be reduced by increasing the muscle percentage in carcasses, which in turn, would reduce backfat thickness (Cannon et al., 1996). The audit results showed that a majority of the carcasses had adequate marbling, and only a small percentage were lacking or had excessive amounts of marbling (Cannon et al., 1996). Some factors that contribute to the increase in intramuscular fat include: poor amino acid balance, *ad-libitum* feeding, and heavy body weight (Bertol et al., 2015).

In contrast, Harsh et al. (2017) reported that the subjective marbling score was not affected directly by hot carcass weight (HCW), and the subjective marbling score actually increased with an increase in hot carcass weight after 20 days of aging (Harsh et al., 2017). With comparing genders, barrows had greater variability in adiposity, which was likely due to the greater ability to deposit fat when compared to gilts (Overholt et al.,

2016). According to Latorre et al. (2007), however, pigs who grow at an increased rate have lower intramuscular fat.

In comparison with other pork quality traits (color, firmness, tenderness, etc.), marbling and intramuscular fat positively correlated with shear force and the change of shear force postmortem (Dilger et al., 2010). The marbling scores were compared with shear force at day 21 of aging. Visual marbling scores also increased until day 20 of aging. At day 21, loins had greater marbling scores and were more tender than at other aging times. There were positive differences between 7, 14, and up to 21 days postmortem (Dilger et al., 2010). This study suggests that loins with higher levels of marbling “experienced more postmortem tenderization than those with lower marbling scores” (Dilger et al., 2010).

GENDER

The effect of gender on carcass quality and yield is well documented. Barrows typically grow faster than gilts because of the higher feed intakes (Geri et al., 1990). Additionally, “carcass cooler shrink was higher in gilts than for barrows” (Cisneros et al., 1995). However, gilts tend to be “leaner than barrows at slaughter weights above 100 kg” (Geri et al., 1990; Boland et al., 1993). Regardless of birth weight, barrows generally have greater levels of intramuscular fat and marbling than gilts (Bertol et al., 2016). Gilts, however, produce leaner hams and higher percentages of lean cuts compared to barrows (Smit et al., 2014; Overholt et al., 2016). Cisneros et al. (1995) reported that barrows had darker lean with finer texture than gilts; however, other muscle quality traits were not affected by gender.

Overholt et al. (2015) reported that barrows had greater backfat depth and less loin depth than gilts and that barrows also use less energy to deposit lean tissue than gilts. Because gilts deposit less fat than barrows, they have greater concentrations of unsaturated fatty acids in adipose tissue (Averette-Gatlin et al., 2002; Lee et al., 2013). This led to suggestions that producers can use sex-specific management strategies to reduce variation in composition and quality traits as they target production towards domestic and international demands.

At similar weights, gilts have larger 10th rib loineye areas and heavier, leaner loins when compared to barrows (Arkfield et al., 2017). Gilts also produced heavier hams when compared with barrows. These findings led Arkfield et al. (2017) to suggest that sex contributes to the overall variability in percent lean of carcasses. It has also been determined that there is a relationship between early postmortem loin quality characteristics and aged loin and chop quality characteristics, but these characteristics do not differ between barrows and gilts (Lowell et al., 2018).

In other aspects, gender had no effect on the moisture or lipid content of the longissimus muscle, nor did it effect color or myoglobin content (Latorre et al., 2004). Barrows did produce heavier carcasses, as previously stated, but dressing percentage was greater in gilts than barrows (Latorre et al., 2004). In agreement with previous findings, Newcom et al. (2002) found that gilts had heavier weights than barrows for all boneless, subprimals, individual muscles, lean, and for all primal cuts except belly. However, Latorre et al. (2003) found no effect of sex on pH, cooking loss, or Warner-Bratzler shear force.

GENOTYPES AND GENETICS

Sire lines can affect many aspects of pork quality in ways that are similar to differences noted between genders. There is a genetic component to all pork carcass attributes such that selection for the attribute will result in positive change for the trait. Pork carcass traits are generally considered to be moderately to highly heritable suggesting that genetic lines can be produced that excel in these traits (Lo et al., 1992). Development of distinct lines that excel in either lean growth or meat quality attributes may offer marketing advantages for both international and domestic markets including genetic companies, packers, and food wholesalers (Dilger et al., 2010). Among the breeds in America, Pietrain-influenced pigs are fast-growing lean pigs commonly used to satisfy the demand of a lean-focused market (Edwards et al., 2003). Likewise, Duroc-based breeds are often used to meet the needs of a meat quality focused market (National Pork Producers Council [NPCC], 1995).

In a study comparing the impact of sire line on tenderness, shear force was reported to be similar between lines during the aging process. The rate and extent of postmortem tenderization were different across the lines (Dilger et al., 2010); however, shear force did not differ after 14 and 21 days of aging. Unfortunately, limited information is available in regard to the aging patterns of different sire lines. van Laack et al. (2001) determined that breed impacted non-aged (24h), but not 21-day aged shear force. Dilger et al. (2010) reported that tenderization in postmortem stages was equal between 2 and 7 days, and 7 and 14 days across sire lines.

Due to the heritability of tenderness and pH, these characteristics could be altered through selection of sire lines (van Laack et al., 2001; Schwab et al., 2006). Lowell et al.

(2018) presented differences among Duroc-sired pigs and Pietrain-sired pigs when studying ultimate pH of loins. Duroc-sired pigs, early ventral visual color from the cut surface of the longissimus dorsi was moderately correlated with 14-day aged pH but only weakly correlated within the Pietrain-sired pigs (Lowell et al., 2018). Duroc-sired pigs also had higher aged postmortem ventral visual marbling scores and ultimate pH compared with the loins from the Pietrain-sired pigs (Lowell et al., 2018). Latorre et al. (2007) reported that marbling score and intramuscular fat were greater in the Synthetic Genex 3000 than the Meishan-derived dam line. However, Wood et al. (2004) stated that the correlation between intramuscular fat and backfat is in fact breed-dependent.

In a study investigating correlations among carcass traits in a lean growth line versus a meat quality line, Lowell et al. (2018) reported that Duroc-sired pigs had significant correlations between 24 h pH and 14-day aged pH of loins. However, early instrumental lightness in color was only moderately correlated to instrumental lightness in the aged loin. Additionally, Pietrain-sired pigs showed a weak correlation between instrumental color and pH.

In a study conducted by Latorre et al. (2004), crossbred pigs (Pietrain x Large White sires bred to Landrace x Large White dams) were used to study gender and increasing slaughter weights effects in the market based on carcass characteristics and meat quality. As already established, Pietrain-sired pigs are fast-growing and early-maturing. This increased rate of growth could contribute to leaner products and heavier carcass weights, which can affect the consumers perceived quality of the product in the changing demand between lean growth line and meat quality line pork.

When comparing purebred Yorkshire and Duroc breeds, Newcom et al. (2002) found that Duroc pigs produced heavier hams and picnic shoulders when compared to Yorkshire pigs, but Yorkshire pigs had heavier loins when compared with Duroc pigs. Newcom et al. (2002) suggested that Duroc pigs can be successfully used in a specialty ham market where two piece hams are desirable (inside and outside). No breed differences were found for the weights of the boneless loin, boneless shoulder, lean, boneless picnic and boston butt (Newcom et al., 2002).

SLAUGHTER WEIGHT AND THE BACON MARKET

Sliced bacon is one of the greatest valued pork products and has increased in value since 2010 (Bureau of Labor Statistics, 2016). The variations in belly weight are attributed to: sex, marketing group, production focus, and season (Arkfield et al., 2017). Production focus, such as feed ration and housing method, had a large impact on belly length and accounted for 22.7% of the total variation, whereas the remaining variation was accounted for by season, sex, and marketing group (Arkfield et al., 2017). In order to maintain and potentially increase the demand for bacon and bacon products, producers must minimize any variability in belly characteristics.

In the Pork Chain Quality Audit conducted by Cannon et al. (1996), thin bellies were one of eight factors that were identified as a major problem within the pork packing industry. To combat this issue, producers and packers sought to increase the slaughter hog weights to produce thicker bellies and more intramuscular fat. With the increase in slaughter weight, Cisneros et al. (1996) stated that the percentage of belly did not change with slaughter weight. However, belly yields increased and were positively correlated with slaughter weights. The change in yield was equal to 0.83 percentage units increased

in yield for each 10-kg increase in slaughter weight (Cisneros et al., 1996). Fredeen (1980) suggested that the increase in slaughter weight was due to an increase in fat content of the belly.

Harsh et al. (2017) studied the effect of hot carcass weights on belly characteristics and found that heavier carcasses produced thicker and firmer bellies. Furthermore, they were able to use hot carcass weights to predict belly quality traits. Similar to the findings of Fredeen (1980), Correa et al. (2008) reported that heavy pigs tend to be fatter and produce thicker bellies. Harsh et al. (2017) also determined that hot carcass weight accounted for 37.81% of the variability in belly thickness. Thinner bellies typically result from leaner pigs which have a greater degree of unsaturated fatty acids and reduce industry slicing yields.

In relation to gender, Cisneros et al. (1996) stated there were no differences in relation to genotypes or sex on belly yields. Conversely, Overholt et al. (2016) presented opposing data; stating fresh belly weight and thickness were more variable for bellies of barrows than bellies of gilts. The bellies of barrows were 4.0% heavier than bellies of gilts (Overholt et al., 2016). As previously discussed, at the same slaughter weights, barrows are heavier and had more intramuscular fat content than gilts when comparing genders. Because of the increase in fat and weight, it can be assumed that barrows will produce deeper, wider, and thicker bellies. Of all the pork primals, the belly has the greatest percentage of fat; thus the belly's weight and thickness correlated with changes in adiposity (Kyle et al., 2014). Because we have already determined that barrows have a higher potential to deposit fat, it can be predicted that belly fatness in barrow carcasses will be greater than in gilts.

SUMMARY

Due to the growing demands from consumers for a more uniform pork product at the retail counter, much research has gone into looking at different effects such as gender, slaughter weights, and genetics. With the past research looking at these effects separately, there is a need to couple these multiple effects to better how they would interact together. Furthermore, consumers have shown favoritism for higher quality (darker lean color with more marbling) pork products. With this growing demand and due to the current pricing of pork carcasses, there is interest in increasing quality within the carcass without negatively impacting the current marketing bases such as fat free lean and % boneless yield. This study focuses on the impact of weight endpoints, genetic differences from sire lines, and gender on pork carcasses as to how they affect not only the consumer but also the producer.

LITERATURE CITED

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CHAPTER 3
THE EFFECTS OF SIRE LINE, SLAUGHTER WEIGHT, AND GENDER ON PORK
QUALITY AND YIELD CHARACTERISTICS¹

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ABSTRACT

Pork continues to be a significant source of highly-valued animal protein for the growing global population. The purpose of this study is to determine the effects of gender and slaughter weight on pork carcass quality attributes, as well as, composition of carcasses from sire lines selected for lean yield or meat quality. In this study, boars from a meat quality line (MQL) and lean yield line (LYL) were mated to females from an international swine genetics company. Pigs from these mating's were used to determine the effects of gender, slaughter weight, and sire line on carcass quality and yield attributes. Pigs were farrowed, weaned, and managed according to a typical industry protocol at the University of Georgia Swine Research Unit (A2018 01-033Y2-A1). As the pigs from a farrowing group reached approximately 23 kg of body weight, litters that contained at least three pigs from each gender were selected for use in the study. From each selected litter, the three pigs within a gender class and closest to the average of the litter weight were selected and randomly assigned a slaughter end weight of 113, 136, or 159 kg. When the pigs reached their assigned slaughter weight they were transported to The University of Georgia Meat Science and Technology Center and harvested under inspection. A total of 26 litters, from 6 farrowing groups, 151 total pigs, were evaluated from 13 litters per sire line. After carcasses were chilled for 24 h, carcass length and carcass muscle score (CMS) were measured. Carcasses were ribbed between the 10th and 11th ribs and tenth rib back fat (TRBF), last rib back fat (LRBF), loineye area, loin pHu, NPPC color and marbling scores, Hunter L*a*b*, and temperature were measured from the longissimus dorsi. Carcasses were fabricated and the following primal and subprimal weights were then collected and recorded: picnic shoulder (405); Boston shoulder (406);

ham (401A); belly (408); and bone-in loin (410); boneless picnic shoulder (405A); boneless Boston shoulder (407); skinless ham (401C); outside ham (402E); inside ham (402F); knuckle (402); skinless belly (409); spareribs (416); boneless loin (413C); tenderloin (415); and boneless sirloin (413D). The skinless belly was further studied measuring length, width, and depth (thickness) as well as firmness. Samples were removed from the longissimus dorsi anterior to the 11th rib for proximate analysis, drip loss, Warner-Bratzler, and slice shear force measurement. Data were analyzed using PROC MIXED procedures in SAS with the fixed effects of gender, sire line, and slaughter endpoint and LSMEANS were separated using LSD. Tenth rib backfat and last rib backfat were greater in MQL ($P<0.01$) than the LYL, and lower in gilts ($P<0.01$) than in barrows. LYL had a greater LEA ($P<0.01$) than MQL, and females had a larger LEA ($P<0.01$) than males. Marbling and firmness scores both were greater in MQL ($P<0.01$) than in LYL. Loin and ham weights, as a percent of hot carcass weight (HCW), were heavier for LYL ($P<0.01$) than MQL, but belly weight, as a percent of HCW was greater for MQL ($P<0.01$) when compared to LYL. Belly dorsal firmness was greatest in MQL lines slaughtered at 159 kg ($P<0.01$). As slaughter endpoint weight increased, bellies became longer, wider, and thicker ($P<0.01$). Proximate analysis showed that moisture was greater in LYL ($P<0.01$) than MQL, however MQL had greater measured crude fat ($P<0.01$) than LYL. Measured protein levels were lower in 113 kg ($P<0.01$) than both 136 and 159 kg. Thaw loss (%) was greater in LYL ($P<0.01$) than in MQL and tenderness was lower in pigs slaughter at 113 kg ($P<0.01$) compared to those slaughtered at 136 and 159 kg. Fat free lean percentage was greater in LYL than MQL ($P<0.01$), in pigs slaughtered at 113 kg compared to those slaughtered at 136 and 159 kg ($P<0.01$),

and in females ($P < 0.01$) compared to males. In summary, there were quality advantages for the MQL pigs compared to LYL, however, yield was superior in the LYL compared to MQL as the MQL pigs were fatter and lighter muscled. Gender differences were similar to those commonly found in the literature and increasing slaughter weights increased primal and subprimal weights and greatly affected carcass composition but had little effect on carcass quality.

INTRODUCTION

In the global marketplace there is a growing demand for animal protein products and pork plays a significant role in filling this demand. However, there exists a dichotomy in the growing demand for pork in that certain populations of consumers demand lean, high protein products (i.e., North America export markets and domestic retail) while other segments of the consuming population prefer higher pork quality attributes (i.e., Pacific rim export markets and domestic foodservice). According to the Study on the Pork Market Worldwide, swine meat provided over 50% of the world-wide meat consumption following an increase of pork imports of 35.1% between 2010-2016 (Soare & Chiurciu, 2017). The hot carcass weight (HCW) of U.S. pork carcasses has increased by 13 kg, representing an increase of more than 0.6 kg/year since 1995 (USDA NASS, 2017). At the same time HCW increased, pork quality traits decreased, which could negatively impact the foodservice and global demand for higher quality pork products. With benefits to producer and packer profitability, the trend for heavier carcass weights is likely to continue (Harsh et al., 2017). Furthermore, product tenderness has declined as slaughter weight has increased (Cisneros et al., 1996). Pork quality is determined by many factors, including: color, exudate, firmness, and marbling. Greater

amounts of marbling in the product has been shown to increase consumer preference ratings because the product was considered “more tender, juicy, and flavorful” (Brewer et al., 2001). Due to the ongoing growth of the pork industry, and the size of pigs continuing to rise, there is a need for a better understanding of how pork quality, genetics, and slaughter weights can affect the pork product. This study focuses on slaughter weight endpoints, genetic differences from sire lines, and gender effects on pork carcass composition and meat quality.

MATERIALS AND METHODS

The University of Georgia Swine Unit mated two composite sire lines, a lean yield line (LYL) and a meat quality line (MQL) to commercial females from an international swine genetics company (n = 13 litters per sire line) during 2017 and 2018. Litters with at least three pigs of each gender were selected for the study. Three barrows and three gilts were chosen from the selected litters (closest in weight to the average of the litter). These pigs (n=151) were randomly assigned to one of three different slaughter weight endpoints (113, 136, and 159 kilograms) once the average of the litter reached 23 kg. The pigs were managed under standard industry procedures for pork production and housed at the University of Georgia Swine Unit until slaughter (A2018 01-033Y2-A1).

Weekly weights were taken on the pigs as they reached their designated slaughter endpoint. When the pigs were within 4.5 kg of their slaughter weight (i.e. 109, 132, 154 kg), they were scheduled to be slaughtered the following week.

Throughout the study, pigs were provided *ad libitum* access to feed that met or exceeded their nutritional requirements during each stage of production.

Carcass Measurements

When the pigs reached their assigned slaughter weights, they were transported to the University of Georgia Meat Science and Technology Center the day prior to harvesting. The pigs were held overnight without access to food, but with free access to water. The next morning, they were harvested under inspection. Slaughter and hot carcass weights were recorded. Carcasses were then chilled at -1°C for approximately 22 to 24 hours. The carcasses were then moved to the holding cooler at 2°C where carcass measurements were collected and recorded. All measurements for this project were taken from the right side of the carcass.

At this time, carcass length from the first rib to the aitch bone and USDA carcass muscle score (CMS) were recorded. Carcasses were ribbed between the 10th and 11th ribs. Carcass temperature was recorded between 22 and 24 hours postmortem from the longissimus dorsi muscle between the 7th and 8th ribs and in the semimembranosus muscle of the ham. Tenth rib backfat and last rib backfat thickness was measured, including the skin.

The longissimus muscle area, at the 10th rib, was traced and later quantified using ImageJ 1.51 d software (Wayne Rasband, National Institutes of Health; Bethesda, MD).

Loin Quality Measurements

Subjective and objective loin quality measurements were then taken from the exposed 10th rib after the loin was given a minimum of 15 min bloom time. Objective color was obtained using a Hunter colorimeter (Hunter MiniScan XE Plus-45/0-L, Hunter Associates Laboratory; Reston, WV). Following calibration, the colorimeter was placed on the loin eye to measure L*, a*, and b* using the illuminate D65 light source.

Subjective color and marbling scores were assessed using the NPPC Color (1-6) and Marbling (1-10) standards. In addition, a lean firmness score was recorded on a 5-point scale (1 = very soft to 5 = very firm). Subjective quality scores were recorded in 0.5 increments of the scale. Lastly, ultimate pH (24 h postmortem; RS 232 Meter; Cole Parmer, Eutech Instruments; Singapore) was measured at the 10th rib in the longissimus dorsi muscle as well as the semimembranosus muscle located on the exposed ham.

Carcass Fabrication

Cold side weights were recorded prior to fabrication for the right sides of all carcasses. Carcasses were then fabricated in the MSTC according to NAMA (2014) specifications with slight modifications. Primal weights were recorded during fabrication of the picnic shoulder (405), Boston shoulder (406), ham (401A), belly (408), and bone-in loin (410). The following subprimal weights were also recorded; skinless ham (401C), outside ham (402E), inside ham (402F), and knuckle (402H), boneless picnic shoulder (405A), boneless Boston shoulder (407; trimmed to 6 mm fat), skinless belly (409), spareribs (416), boneless loin (413C; trimmed to 0 mm fat), tenderloin (415), and boneless sirloin (413D; trimmed to 6 mm fat).

Following the separation from the loin and belly, but prior to ham fabrication, hams (401A) were allowed to bloom 15 min. Hunter colorimeter measurements were then collected from the exposed gluteus medius and gluteus profundus muscles. Following L*, a*, and b* collection, pH (RS 232 Meter; Cole Parmer, Eutech Instruments; Singapore) from both muscles was also recorded.

Belly Dimensions

Belly length (at the midpoint of the width) and width (at the midpoint of the length) were measured. Thickness of the belly was measured, at the midpoint of the width, in the following 5 locations: the cranial end, then $\frac{1}{4}$ of the length from the cranial end, $\frac{1}{2}$ of the length from the cranial end, $\frac{3}{4}$ of the length from the cranial end, and the caudal end.

Belly firmness was collected using the “flop method” (Thiel-Cooper et al., 2001). The inside distance from end to end on the dorsal and ventral sides of the belly were recorded.

Sample Removal

Loin chops, collected from the 11-13th rib region, for the following quality and composition determinations were collected: proximate analysis (1.3 cm thick for protein, moisture, and fat), slice shear force and Warner-Bratzler shear force (2.5 cm thick), and 24 hour drip loss (1.3 cm thick).

The slice and Warner-Bratzler shear force samples were vacuum-packaged and held at 2°C for 14 days, then transferred to freezer at -10°C until subsequent analysis. Proximate analysis samples were frozen at -10°C post collection until further processed.

Drip Loss

Drip loss samples were prepared and processed according to procedures from Honikel (1997). Post fabrication, longissimus dorsi samples were cut into approximately 50-60 grams samples trimmed of all fat. Samples were suspended by a fishing hook, and stored at 2°C for 24 hours in a sealed bag to collect exudate. Bags and samples were hung in such a manner to eliminate contact. After 24 hours of suspension, samples were blotted

on each side and reweighed to calculate a drip loss percentage ((initial weight-frozen weight)/(initial weight)*100).

Proximate Analyses

Proximate analysis samples were thawed overnight, minced, frozen in liquid nitrogen, and powder homogenized in a Waring commercial blender (Model 34BL97, Dynamic's Corporation of America, New Hartford, CT).

For protein calculation (AOAC, 2006), homogenized samples were weighed out to 0.2000-0.2099 grams in triplicates and placed into a LECO FP-628 Nitrogen Analyzer (LECO Corp, St. Joseph, MI) to determine nitrogen content, crude protein (CP) was calculated using the following equation: $CP = \%N \times 6.25$.

For moisture (AOAC, 2006) and lipid determination (Komarek et al., 2004), homogenized samples were weighed to 1.0000-1.4999 grams in duplicate, in filter bags (XT4, Ankom Technology, Macedon, NY), and dried overnight in an oven at 100°C overnight. The following morning, samples were removed from the oven and weights were collected to calculate moisture loss using the following equation: $\text{moisture (\%)} = 100 \times ((\text{filter bag weight} + \text{sample weight}) - \text{weight after drying}) / \text{sample weight}$. After drying, samples were placed into an Ankom Fat Extractor XT15 (Ankom Technology, Macedon, NY) for approximately 2 h. Samples were then placed in an oven at 100°C for 15 min. After the post extraction drying, the samples were placed in a desiccator for approximately 15 min and weighed. Lipid content was calculated using the following equation: $\text{fat (\%)} = ((\text{pre-dried sample weight} - \text{dried weight after extraction}) \times 100) / \text{wet sample weight}$.

Shear Force Evaluation

Frozen chops for Warner-Bratzler shear were removed from freezer storage and vacuum bags and frozen weights were recorded. The chops were then placed on a tray and thawed overnight at 4°C. The following day, a thawed weight was recorded prior to cooking. Cooper-constantan thermocouples were inserted into sample chops in the approximate geometric center of the chops and initial temperatures were recorded using a potentiometer (12-Channel Scanning Thermocouple Thermometer, Cole-Parmer Instrument Co., Vernon Hills, Illinois). Chops were cooked using a George Foreman clamshell grill (George Foreman, Spectrum Brands, Middleton, WI) to an internal temperature of 65°C while recording cook time. As the cooked chops were removed from the grill, cooked weight was recorded to determine cook loss and samples were placed on a tray to chill overnight. After chilling, six 1.27 cm diameter core samples taken parallel with the muscle fibers were collected and analyzed using an Instron Universal Testing Machine (5 N load cell; Instron Corp. Worldwide Headquarters; Dual Column Model 3365; Norwood, MA) using a 1.02 mm thick blade shaped to centralize the core travelling 500 mm/min perpendicular through muscle fibers (AMSA, 1995).

Frozen chops for slice shear were removed from freezer storage and vacuum bags and frozen weights were recorded. The chops were then placed on a tray and thawed overnight at 4°C. The following day, a thawed weight was recorded prior to cooking. Cooper-constantan thermocouples were inserted into sample chops in the approximate geometric center of the chops and initial temperatures were recorded using a potentiometer (12-Channel Scanning Thermocouple Thermometer, Cole-Parmer Instrument Co., Vernon Hills, Illinois). Chops were cooked using a George Foreman

clamshell grill (George Foreman, Spectrum Brands, Middleton, WI) to an internal temperature of 65°C while recording cook time. As the cooked chops were removed from the grill, cooked weight was recorded to determine cook loss. Two pieces that were 1 cm thick and 5 cm long, from the lateral end of the loin chop were cut using a 45° slice box and a two-bladed knife to cut parallel with the muscle fibers. Samples were then analyzed using an Instron Universal Testing Machine using a 1.02 mm thick blade travelling 500 mm/min perpendicular through muscle fibers (Wheeler et al., 2005).

Statistical Analysis

Data were analyzed using PROC MIXED procedures (SAS 9.4, SAS Inst., Inc., Cary, NC) with the fixed, main effects of sire line, gender, and slaughter endpoint. Main effects and their interactions were tested. Animal was the experimental unit. The LINES function of SAS was used for main effect interactions. Least squares means were separated using least significant difference procedures. Results were deemed significant at $\alpha \leq 0.05$. Degree of doneness for both shear force measurements was used as a covariate.

RESULTS AND DISCUSSION

Carcass Composition

For carcass composition (**Table 3.1**), slaughter weight, hot carcass weight, and dressing percentage did not differ ($P > 0.15$) across sire line or gender. As expected, slaughter weight, hot carcass weight, and dressing percentage increased ($P < 0.01$) as slaughter weight endpoint increased, although dressing percentage was not different between 113 and 136 kg.

The MQL carcasses had greater ($P<0.01$) 10th rib backfat and last rib backfat depth than that of the LYL carcasses. Tenth rib and last rib back fat increased ($P<0.01$) across all slaughter weight endpoints. As expected from previous research, both back fat measurements were greater ($P<0.01$) in males than in females (Overholt et al. 2015, Geri et al., 1990; Boland et al., 1993). In a similar study comparing sire lines, Latorre et al. (2008), reported that differences in genetic lines could also contribute to leaner carcasses.

Carcasses from LYL had greater ($P<0.01$) loin eye area than those from MQL, and females had larger ($P<0.01$) loin eye size than males. Furthermore, as slaughter weights increased loin eye area increased ($P<0.01$). However, there were no main effect interactions ($P\geq 0.27$) for loin eye area. Carcass length increased ($P<0.01$) as slaughter endpoint increased, but there were no differences ($P\geq 0.23$) between gender or sire line. Carcass muscle score (USDA) was different between sire lines with LYL having greater muscling than MQL ($P<0.01$). Because the fat free lean (FFL) equation includes backfat and loin eye area, differences found to be similar to those two compositional factors. The LYL carcasses had a higher ($P<0.01$) percentage of FFL than MQL due to its advantages in trimness and muscling. Likewise, gilt carcasses had advantages in trimness and muscling compared to barrow carcasses thus greater ($P<0.01$) FFL.

Carcass Quality

Ultimate pH (pHu), collected 22-24 h postmortem, is considered an important carcass quality attribute (**Table 3.2**). Neither loin or ham pHu was different ($P\geq 0.07$) across any of the main effects. In agreement with the pHu findings, subjective NPPC color scores were similar across the three main effects ($P>0.24$). The MQL loins had greater ($P<0.01$) subjective marbling scores than LYL loins and males had greater

($P < 0.01$) marbling scores than females. This was expected as there is a known relationship between subcutaneous fat thickness and intramuscular fat content (Smit et al., 2014). Firmness scores for the longissimus muscle showed that MQL loins were firmer ($P < 0.01$) than LYL loin muscle. In comparison of sire lines, there appears to be a relationship between intramuscular fat content and loin muscle firmness, as marbling scores and firmness scores are higher in the MQL vs LYL. However, this same relationship is not apparent in the comparison of genders, as barrow carcasses had greater levels of intramuscular fat than gilt carcasses while firmness scores were similar.

Objective color from the Hunter colorimeter showed no difference ($P > 0.12$) across the main effects for lightness (L^*) measurements. Redness (a^*) and yellowness (b^*) values were similar ($P > 0.17$) for the various slaughter weight endpoints, however, barrows had a more yellow (b^*) and red (a^*) color ($P < 0.02$) in the exposed lean of the loin.

Drip loss did not differ ($P > 0.22$) between slaughter weight endpoints. However, LYL longissimus had greater ($P < 0.04$) drip loss (%) than MQL longissimus and gilts had a greater ($P < 0.01$) percentage drip loss than barrows. These findings are consistent with previous research showing that drip loss decreases as marbling increases (Dilger et al., 2010), and slaughter weight does not influence the percent drip loss (Bertol et al., 2015).

Ham temperatures, recorded 22-24 h postmortem, were not different ($P > 0.35$) across sire line and gender, however, as slaughter weight increased the 22-24 h temperature of the ham increased ($P < 0.01$). Loin 22-24 h temperatures were different ($P < 0.01$) across all main effects. The LYL loin temperatures were lower ($P < 0.01$) than MQL which may be accredited to the differences in backfat between the sire lines.

Furthermore, barrows had greater loin temperatures than gilts, which may also be due to differences in fat thickness between genders. Similar to the increases in 22-24 h ham temperature, loin temperatures increased as slaughter weight endpoint increased. An interaction ($P<0.04$) between sire line and slaughter endpoint (**Table 3.11**) was seen for loin 22-24 h temperature. This interaction showed that loins from MQL carcasses at the 136 and 159 kg endpoints had greater ($P<0.05$) temperatures LYL loins at the same weight endpoints. However, at the 113 kg slaughter weight endpoint, there was no difference ($P>0.05$) in loin temperature across sire line.

Ham Quality

Table 3.3 shows various measures from the gluteus medius and gluteus profundus muscles in the cut face of the skin-on ham. The pHu from the gluteus medius and gluteus profundus did not differ ($P>0.17$) for any main effect. Lightness (L^*) measurements from both muscles showed that MQL hams were lighter colored ($P<0.01$) than LYL hams. Gluteus medius a^* and b^* measures were different ($P<0.01$) for 113 kg compared to both 136 and 159 kg. There were three-way interactions for gluteus profundus L^* and a^* ($P=0.05$). Lightness (L^*) values were highest in MQL barrows slaughtered at 136 kg and these measurements differed from LYL gilts at 113 kg and LYL barrows slaughtered at 136 and 159 kg. LYL gilts with an endpoint of 113 kg were darker than all MQL gluteus profundus muscle measurements, suggesting that LYL and gilts have darker gluteus profundus than the MQL and barrows, respectively. Gluteus profundus a^* values showed tendencies ($P=0.08$) to be lesser at 113 kg slaughter weight endpoint MQL.

Fabrication Weights

Table 3.4 shows primal and subprimal weights. Four of the five primals were heavier in the LYL than MQL ($P<0.01$) carcasses. Bellies were the only primal that were heavier ($P=0.04$) in MQL than LYL. This is most likely due to fat thickness differences between sire lines that was found in this study. Boneless Boston shoulder and sparerib weights were not different ($P>0.43$) between sire lines. Boneless picnic, boneless loin, skinless ham, inside ham, outside ham, and knuckle weights were heavier ($P<0.01$) in LYL than MQL and tenderloin and boneless sirloin weights tended ($P<0.07$) to be heavier in LYL than MQL. Weight of FFL was significantly heavier ($P<0.01$) for LYL when compared to MYL.

As expected, all primal and subprimal weights increased ($P<0.01$) as slaughter endpoint increased. Furthermore, FFL % increased ($P<0.01$) as endpoint increased.

Barrows were superior to gilts for skin on belly and skinless belly weights ($P<0.01$). Gilts, however, had heavier ($P<0.01$) whole loins, boneless loins, tenderloins, inside hams, and knuckles than barrows. Ham primal weight was not found to be different ($P\geq 0.98$) between genders, which may be explained by the additional subcutaneous fat of the barrows being included in the weight.

Primal and subprimal yields, as a percentage of side weight, are shown in **Table 3.5**. Similar differences between sire lines for primal and subprimal yields were seen as in weights. Lean yield line had greater yields ($P<0.01$) for all primals except the belly, where MQL was greater ($P<0.01$). Percent boneless Boston shoulder, sparerib, and boneless sirloin were not different among sire lines ($P>0.13$). Percent boneless picnic,

boneless loin, tenderloin, and all subprimals from the ham were greater ($P<0.01$) in LYL carcasses than MQL.

The effect of slaughter weight endpoint on primal and subprimal yields showed that belly and skinless belly yields increased as slaughter weight endpoint increased, while yields for all other primals and subprimals were either similar or decreased as slaughter weight endpoint increased. For belly and skinless belly yields, there were no differences at the 113 and 136 kg endpoints; however, both were lower than yields at 159 kg endpoint. Cisneros et al. (1996) stated that “the percentage of belly did not change with slaughter weight,” however, their heaviest endpoint was lower than the heaviest weight endpoint in the current study. Yield differences across the four leaner primals (Boston shoulder, picnic shoulder, loin, and ham) and their corresponding subprimals generally showed that yields were lower at the 159 versus the 113 kg endpoint, most likely due to differences in fatness across the slaughter weight endpoints, especially in the subprimal yields where subcutaneous fat was trimmed to a constant level.

Primal and subprimal yields differed across gender in the following primals: belly, loin, and ham. Males had a greater percentage yield of belly and skinless belly ($P<0.01$), which is influenced by the amount of fat on the barrow carcasses. Gilts were superior to barrows in the yields of loin and ham primals ($P<0.01$). Furthermore, the subprimals from the loin and ham showed greater percent yields for gilts compared to barrows ($P<0.03$).

Interactions were seen for the yield of skinless ham and inside ham. The interaction between sire line and gender was significant for skinless ham yield (**Table 3.10**), in that LYL females and LYL males did not differ in skinless ham yields but had

greater ($P<0.05$) yields than MQL females and males and MQL gilts had greater ($P<0.05$) skinless ham yields than MQL barrows. The interaction between slaughter weight and gender for inside ham yield showed that barrows at all three slaughter weight endpoints and gilts at the 159 kg endpoint were similar ($P<0.05$) in inside ham yields and lower ($P<0.05$) than inside ham yields for either 113 kg and 139 kg females.

Belly Measurements

Belly length and width (**Table 3.6**) were not different among sire lines ($P>0.23$). Average belly thickness was not different between sire lines ($P=0.55$), although belly thickness $\frac{1}{4}$ of the distance from cranial to caudal end was different ($P<0.01$) showing MQL was thicker at this location than LYL. Dorsal and ventral firmness measurements showed that MQL bellies were firmer than LYL bellies ($P<0.01$).

As slaughter weight endpoint increased, belly length, width, and thickness also increased ($P<0.01$). This is similar to previous research that found heavier pigs tended to be fatter and produce thicker bellies (Fredeen et al., 1980, Correa et al., 2008). Dorsal firmness increased ($P<0.05$) at each slaughter weight endpoint following a similar pattern to thickness. Ventral firmness showed that bellies from the 136 and 159 kg slaughter weight endpoints were similar ($P>0.05$) but different ($P<0.05$) from the 113 kg slaughter weight endpoint.

Males tended to have thicker bellies on average than females ($P<0.07$), and male's bellies were thicker at the $\frac{1}{4}$ and $\frac{1}{2}$ location along the belly compared to females ($P<0.01$). Males also had more firm dorsal measurements than females ($P<0.01$).

A sire line by slaughter endpoint interaction was found for dorsal firmness. Lean yield line and MQL bellies at 113 kg endpoint were the least firm. Meat quality line at

136 kg and LYL at 136 and 159 kg were similar, but MQL at 159 kg was firmer than all other groups. Meat quality line was fatter than LYL and as previous research found as weight increased, so did belly thickness (Fredeen et al., 1980, Correa et al., 2008). These results differ than those seen in Cannon et al. (1996) study which suggests as slaughter weight increases, belly thickness decreased.

Proximate Analysis of the Longissimus dorsi

Crude protein of the longissimus muscle (**Table 3.7**) was not different between sire lines ($P=0.11$), however sire lines differed for percent moisture and crude fat. Lean yield line had a greater moisture percentage than MQL ($P<0.01$), however MQL had a higher crude fat percentage than LYL ($P<0.01$). The effect of slaughter weight endpoint showed that the lighter slaughter weight (113 kg) had less percent crude protein ($P<0.01$) than other slaughter weight endpoints. Percent moisture was not different between slaughter endpoints ($P=0.54$). Crude fat decreased as slaughter weights increased with 113 kg being significantly different ($P<0.01$) than 159 kg, however 136 kg was similar to both. Females had a higher crude protein content than males ($P=0.04$). Also, gilts tended to have less crude fat than that found in barrows ($P=0.07$). The results from proximate data are consistent with subjective data from this research that show gilts have higher lean and lower fat percentage.

An interaction ($P<0.05$) between sire line and weight endpoint was found for crude protein content. Within a sire line, the 113 kg slaughter endpoint was lower than the 136 and 159 kg endpoints; however, only at the 159 kg slaughter endpoint did the LYL have more ($P<0.05$) crude protein than MQL.

Shear Force Determination

Objective tenderness was measured by both Warner-Bratzler shear force (WBSF)(**Table 3.8**) and slice shear force (SSF)(**Table 3.9**). Degree of doneness was used as a covariate for both procedures. There were no significant differences for initial and final temperatures ($P>0.20$) across any of the main effects. Cook time was not different for sire line or gender ($P>0.30$). However, chops from 113 kg weight endpoint cooked faster ($P<0.01$) than 136 and 159 kg endpoint chops. Thaw loss percentage was greater for LYL than MQL ($P<0.01$). Total loss percentage, which includes cook and thaw loss, was also greater for LYL than MQL ($P<0.01$). Total loss was least ($P<0.01$) for the 113 kg slaughter endpoint when compared to 136 kg, but not different compared to 159 kg. Longissimus dorsi WBSF tenderness was not affected ($P>0.92$) by sire line or gender; however, chops for the 113 kg slaughter endpoint required less force ($P<0.01$) for Warner-Bratzler shear than the 136 and 159 kg endpoints. Cisneros et al. (1996) found similar results as increasing slaughter weights were associated increased shear force. An interaction for sire line by gender was significant for WBSF kg. Meat quality line females were more tender than MQL males, however in LYL, barrows were more tender than gilts.

For slice shear force, thaw loss percentage was different across gender ($P=0.01$) as chops from females lost a greater percent of their weight than males. Lean yield line, when compared with MQL, had a greater ($P=0.01$) percent of thaw loss as well.

Tenderness, measured by SSF, did not differ for sire line or gender ($P>0.18$), which is consistent with the findings for WBSF. The effect of slaughter endpoint weight on SSF was similar to that noted in WBSF, as chops from the 113 kg slaughter weight endpoint

were more tender ($P<0.01$) than either the 136 or 159 kg endpoint. A three-way interaction of the main effects was found for SSF kg (**Table 3.13**). Slice shear force increased from 113 to 136 kg slaughter weight endpoint for MQL barrows and gilts and LYL barrows and gilts. Furthermore, data showed that MQL gilts and LYL males had a tendency to increase as slaughter weight increased; however, for MQL barrows and LYL gilts at 159 kg slaughter weight endpoint, the slice shear force value lowered. The biological explanation for these trends is uninterpretable.

IMPLICATIONS

The major differences between sire lines were seen in advantages in lean yield for the LYL over MQL, while advantages in meat quality existed for the MQL over the LYL, primarily in the form of greater levels of intramuscular fat in the loin. The current U.S. marketplace places a greater emphasis on lean yield than meat quality. However, as global demand for high quality pork increases and pork makes greater progress in the foodservice sector it will be important for U.S. producers to have the ability to target the growing quality demand. As slaughter weight endpoint increased, there was a decrease in lean yield due primarily to fat accretion in the heavier carcasses. Gilts also had lean yield advantages over barrows which is consistent across a large body of literature. The sole yield advantage for the MQL was in the belly. Bellies from the MQL would be more desirable for bacon manufacturing for bellies were thicker and firmer than the LYL bellies. This is an important consideration due to the value of the belly in comparison to other primals. Future research should focus on producing sire lines that can excel, or at least meet minimum standards, for both yield and meat quality attributes. This would allow producers the flexibility to target multiple markets for their product. Further

research and education on consumer acceptability and demand could change the way pork quality is viewed. Follow-up experiments investigating feed and weight gain variables could be carried out separating the LYL and MQL as well as single gender management schemes to maximize productivity and profitability.

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Table 3.1: Effect of sire line (S), slaughter weight endpoint (W), and gender (G) on carcass composition

Variable	Sire Line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*G	S*W	W*G	S*W*G
Slaughter wt, kg	137.6	136.2	0.17	114.8 ^a	138.1 ^b	157.7 ^c	<0.01	136.9	136.8	0.90	0.87	0.99	0.73	0.89
Hot carcass wt, kg	102.1	101.0	0.15	84.5 ^a	102.2 ^b	118.0 ^c	<0.01	101.8	101.3	0.52	0.95	0.82	0.57	0.87
Dressing %	74.2	74.1	0.80	73.6 ^a	74.0 ^a	74.8 ^b	<0.01	74.3	74.0	0.34	0.67	0.46	0.89	0.31
Side wt, kg	50.4	50.1	0.47	41.8 ^a	50.5 ^b	58.4 ^c	<0.01	50.4	50.0	0.34	0.99	0.44	0.69	0.41
10th rib backfat depth, mm	22.2	28.2	<0.01	20.8 ^a	25.2 ^b	29.6 ^c	<0.01	27.3	23.1	<0.01	0.31	0.62	0.57	0.60
Last rib backfat depth, mm	26.2	29.0	<0.01	23.3 ^a	27.8 ^b	31.8 ^c	<0.01	28.9	26.3	<0.01	0.99	0.75	0.50	0.41
Loin eye area, cm ²	51.5	48.9	0.01	44.5 ^a	51.2 ^b	54.8 ^c	<0.01	48.4	51.9	<0.01	0.82	0.64	0.79	0.27
Carcass length (cm)	89.4	88.9	0.23	85.6 ^a	89.0 ^b	92.9 ^c	<0.01	88.9	89.5	0.18	0.27	0.93	0.94	0.65
Carcass muscle score, 1-3	2.4	2.3	<0.01	2.2 ^a	2.4 ^b	2.5 ^b	<0.01	2.4	2.4	0.92	0.81	0.64	0.85	0.58
% Fat Free Lean*	52.6	49.8	<0.01	52.6 ^a	51.3 ^b	49.8 ^c	<0.01	50.0	52.5	<0.01	0.49	0.83	0.73	0.32

* Calculated using the equation $(8.5876 - (21.8957 \times 10^{\text{th}} \text{ rib fat, in}) + (3.0047 \times \text{loin eye area, in}^2) + (.4650 \times \text{hot carcass wt, lbs.})) / \text{hot carcass wt} \times 100$ (Griffin, 2011)

^{a b c} Means differ (P<0.05)

Table 3.2: Effect of sire line (S), slaughter weight endpoint (W), and gender (G) on carcass quality

Variable	Sire Line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction Pr>F			
	LYL	MQL		113	136	159		M	F		S*G	S*W	W*G	S*W*G
pHu														
Longissimus dorsi	5.47	5.49	0.42	5.48	5.48	5.48	0.99	5.49	5.47	0.54	0.45	0.72	0.95	0.06
Semimembranosus	5.72	5.73	0.81	5.72	5.7	5.75	0.60	5.76	5.69	0.07	0.65	0.62	0.41	0.12
NPPC Scores														
Color, 1-6	3.3	3.2	0.24	3.2	3.3	3.3	0.80	3.3	3.3	0.97	0.94	0.96	0.71	0.69
Marbling, 1-10	2.2	2.7	<0.01	2.5	2.4	2.3	0.31	2.6	2.3	0.03	0.91	0.46	0.66	0.17
Firmness, 1-5	2.6	2.9	<0.01	2.8	2.8	2.6	0.42	2.8	2.7	0.56	0.88	0.49	0.11	0.21
L*	57.4	58.1	0.22	57.1	58.1	57.9	0.40	57.2	58.2	0.12	0.43	0.89	0.48	0.49
a*	8.9	8.3	<0.01	8.8	8.4	8.7	0.31	8.9	8.4	0.02	0.35	0.70	0.57	0.60
b*	17.2	17.4	0.38	17.1	17.2	17.6	0.17	17.6	17.0	<0.01	0.12	0.09	0.52	0.67
% Drip Loss	3.2	2.7	0.04	2.7	3.2	2.9	0.22	2.5	3.4	<0.01	0.56	0.54	0.99	0.33
Loin 24 h Temp. °C	-0.58	-0.39	<0.01	-0.76 ^a	-0.51 ^b	-0.19 ^c	<0.01	-0.40	-0.57	<0.01	0.09	0.04	0.70	0.58
Ham 24 h Temp °C	0.82	0.69	0.35	-0.03 ^a	0.79 ^b	1.51 ^c	<0.01	0.78	0.73	0.67	0.18	0.59	0.87	0.74

^{a b c} Means differ (P<0.05)

Table 3.3: Effect of sire line (S), slaughter weight endpoint (W), and gender (G) on ham quality for the gluteus medius and gluteus profundus

Variable	Sire Line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction			
	LYL	MQL		113	136	159		M	F		S*G	S*W	W*G	S*W*G
Gluteus medius														
pHu	5.48	5.48	0.96	5.51	5.47	5.46	0.40	5.49	5.47	0.59	0.99	0.45	0.69	0.26
L*	49.2	52.3	<0.01	50.7	50.3	51.30	0.55	50.6	50.9	0.67	0.49	0.73	0.72	0.09
a*	11.2	10.9	0.25	10.3 ^a	11.2 ^b	11.7 ^b	<0.01	11.2	11.0	0.42	0.67	0.84	0.60	0.07
b*	17.4	17.8	0.17	16.8 ^a	17.8 ^b	18.2 ^b	<0.01	17.3	17.8	0.12	0.97	0.94	0.23	0.98
Gluteus profundus														
pHu	5.68	5.69	0.94	5.70	5.69	5.66	0.74	5.71	5.66	0.17	0.70	0.52	0.69	0.16
L*	40.3	42.7	<0.01	41.2	41.8	41.5	0.80	41.7	41.3	0.55	0.90	0.93	0.66	0.05
a*	17.0	16.5	0.18	16.1 ^a	17.1 ^b	16.9 ^{ab}	0.08	16.6	16.9	0.48	0.25	0.96	0.92	0.05
b*	18.5	18.5	0.96	18.1	18.7	18.6	0.48	18.4	18.5	0.86	0.27	0.66	0.69	0.60

^{a b c} Means differ (P<0.05)

Table 3.4: Effect of sire line (S), slaughter weight endpoint (W), and gender (G) on primal weights (kg) and their subprimals (kg)

Variable	Sire Line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction			
	LYL	MQL		113	136	159		M	F		S*G	S*W	W*G	S*W*G
Picnic	5.3	5.1	0.01	4.4 ^a	5.2 ^b	5.9 ^c	<0.01	5.2	5.2	0.43	0.77	0.13	0.33	0.29
Boneless Picnic	3.9	3.7	0.01	3.3 ^a	3.9 ^b	4.3 ^c	<0.01	3.8	3.8	0.56	0.36	0.21	0.66	0.77
Boston Shoulder	4.5	4.3	0.03	3.7 ^a	4.4 ^b	5.0 ^c	<0.01	4.3	4.4	0.22	0.33	0.70	0.41	0.51
Boneless Boston	3.6	3.5	0.43	3.0 ^a	3.7 ^b	4.0 ^c	<0.01	3.6	3.5	0.61	0.36	0.35	0.23	0.83
Belly	8.2	8.4	0.04	6.7 ^a	8.2 ^b	10.0 ^c	<0.01	8.5	8.2	<0.01	0.38	0.36	0.82	0.74
Belly, Skinless	7.2	7.4	0.06	5.9 ^a	7.3 ^b	8.9 ^c	<0.01	7.5	7.2	<0.01	0.37	0.39	0.99	0.78
Sparerib	1.9	1.9	0.72	1.6 ^a	1.9 ^b	2.1 ^c	<0.01	1.9	1.9	0.48	0.72	0.14	0.81	0.81
Loin	11.3	11.0	0.02	9.4 ^a	11.3 ^b	12.9 ^c	<0.01	11.0	11.3	0.02	0.76	0.82	0.97	0.29
Boneless Loin	4.1	3.7	<0.01	3.3 ^a	3.9 ^b	4.5 ^c	<0.01	3.8	4.0	<0.01	0.77	0.56	0.89	0.30
Tenderloin	0.63	0.61	0.06	0.52 ^a	0.62 ^b	0.72 ^c	<0.01	0.60	0.64	<0.01	0.26	0.41	0.17	0.68
Boneless Sirloin	1.3	1.3	0.07	1.0 ^a	1.3 ^b	1.5 ^c	<0.01	1.3	1.3	0.06	0.09	0.83	0.95	0.67
Ham	12.0	11.4	<0.01	9.8 ^a	11.7 ^b	13.6 ^c	<0.01	11.7	11.7	0.98	0.07	0.40	0.60	0.46
Skinless Ham	11.2	10.6	<0.01	9.2 ^a	11.0 ^b	12.6 ^c	<0.01	10.9	11.0	0.28	0.07	0.80	0.44	0.99
Inside	2.4	2.2	<0.01	2.0 ^a	2.4 ^b	2.6 ^c	<0.01	2.3	2.4	<0.01	0.11	0.60	0.26	0.84
Outside	2.8	2.6	<0.01	2.3 ^a	2.8 ^b	3.1 ^c	<0.01	2.7	2.8	0.07	0.17	0.43	0.57	0.63
Knuckle	1.5	1.3	<0.01	1.2 ^a	1.4 ^b	1.6 ^c	<0.01	1.4	1.4	<0.01	0.58	0.22	0.71	0.31
Fat Free Lean*	118.1	110.6	<0.01	98.1 ^a	115.4 ^b	129.5 ^c	<0.01	111.9	116.8	<0.01	0.50	0.99	0.92	0.42

* Calculated using the equation $(8.5876 - (21.8957 \times 10^{\text{th}} \text{ rib fat, in}) + (3.0047 \times \text{loin eye area, in}^2) + (.4650 \times \text{hot carcass wt, lbs.}))$ (Griffin, 2011)

^{a b c} Means differ (P<0.05)

Table 3.5: Effect of sire line (S), slaughter weight endpoint (W), and gender (G) on primals and their subprimals as a percentage of side weight

Variable	Sire Line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction			
	LYL	MQL		113	136	159		M	F		S*G	S*W	W*G	S*W*G
%Picnic	10.5	10.2	0.04	10.6 ^a	10.4 ^{ab}	10.1 ^b	0.03	10.4	10.3	0.56	0.98	0.14	0.28	0.12
%Boneless Picnic	7.8	7.5	0.05	7.9 ^a	7.7 ^{ab}	7.4 ^b	0.04	7.7	7.6	0.84	0.45	0.21	0.83	0.56
%Boston Shoulder	8.9	8.6	0.03	8.9 ^a	8.7 ^{ab}	8.5 ^b	0.12	8.6	8.8	0.06	0.27	0.74	0.55	0.88
%Boneless Boston	7.2	7.0	0.44	7.1	7.3	6.9	0.22	7.1	7.1	0.80	0.30	0.33	0.27	0.78
%Belly	16.2	16.8	<0.01	16.1 ^a	16.3 ^a	17.1 ^b	<0.01	16.8	16.2	<0.01	0.31	0.87	0.80	0.66
%Belly, Skinless	14.3	14.8	<0.01	14.1 ^a	14.4 ^a	15.2 ^b	<0.01	14.9	14.3	<0.01	0.30	0.81	0.84	0.74
%Sparerib	3.8	3.8	0.80	3.8	3.8	3.7	0.22	3.7	3.8	0.20	0.76	0.20	0.62	0.56
%Loin	22.5	22.0	0.02	22.4	22.4	22.0	0.32	21.9	22.7	<0.01	0.64	0.86	0.82	0.64
%Boneless Loin	8.1	7.5	<0.01	7.8	7.8	7.7	0.80	7.5	8.1	<0.01	0.76	0.54	0.82	0.44
%Tenderloin	1.3	1.2	0.06	1.2	1.2	1.2	0.71	1.2	1.3	<0.01	0.21	0.38	0.53	0.90
%Boneless Sirloin	2.6	2.5	0.13	2.5 ^a	2.7 ^b	2.6 ^{ab}	0.07	2.5	2.6	0.03	0.09	0.70	0.95	0.91
%Ham	23.9	22.7	<0.01	23.6	23.2	23.2	0.41	23.2	23.5	0.39	0.06	0.25	0.31	0.15
%Skinless Ham	22.3	21.3	<0.01	22.1 ^a	21.7 ^{ab}	21.5 ^b	0.04	21.6	22.0	0.02	0.05	0.53	0.51	0.55
%Inside	4.9	4.4	<0.01	4.7 ^a	4.7 ^{ab}	4.5 ^b	0.03	4.5	4.8	<0.01	0.11	0.58	0.04	0.59
%Outside	5.6	5.3	<0.01	5.5 ^a	5.5 ^a	5.2 ^b	0.02	5.3	5.5	0.02	0.12	0.18	0.74	0.46
%Knuckle	3.0	2.6	<0.01	2.9 ^a	2.8 ^b	2.7 ^b	<0.01	2.7	2.9	<0.01	0.38	0.36	0.71	0.12

^{a b c} Means differ (P<0.05)

Table 3.6: Effect of sire line (S), slaughter weight endpoint (W), and gender (G) on length, thickness, and firmness of the belly

Variable	Sire Line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction			
	LYL	MQL		113	136	159		M	F		S*G	S*W	W*G	S*W*G
Length, cm	74.2	73.8	0.43	69.3 ^a	74.8 ^b	77.9 ^c	<0.01	74.1	73.9	0.86	0.90	0.09	0.71	0.78
Width, cm	28.8	28.4	0.23	26.7 ^a	28.4 ^b	30.7 ^c	<0.01	28.4	28.8	0.16	0.04	0.36	0.92	0.59
Thickness														
Cranial, cm	4.3	4.4	0.88	3.8 ^a	4.4 ^b	4.9 ^c	<0.01	4.4	4.3	0.63	0.68	0.91	0.44	0.16
¼ distance, cm	3.1	3.4	<0.01	2.8 ^a	3.2 ^b	3.7 ^c	<0.01	3.4	3.1	<0.01	0.48	0.64	0.24	0.41
½ distance, cm	2.5	2.5	0.70	2.2 ^a	2.5 ^b	2.8 ^c	<0.01	2.7	2.3	<0.01	0.99	0.98	0.99	0.87
¾ distance, cm	2.9	2.9	0.63	2.6 ^a	2.9 ^b	3.2 ^b	<0.01	2.9	2.9	0.84	0.85	0.23	0.49	0.50
Caudal, cm	4.0	4.1	0.65	3.4 ^a	4.2 ^b	4.5 ^b	<0.01	4.1	4.0	0.52	0.89	0.47	0.77	0.54
Average, cm	3.4	3.4	0.55	3.0 ^a	3.4 ^b	3.8 ^c	<0.01	3.5	3.3	0.07	0.98	0.58	0.74	0.22
Firmness														
Dorsal, cm	9.9	12.0	<0.01	8.6 ^a	11.3 ^b	13.0 ^c	<0.01	12.3	9.6	<0.01	0.48	0.04	0.53	0.57
Ventral, cm	15.8	18.9	<0.01	14.4 ^a	18.3 ^b	19.2 ^b	<0.01	17.7	16.9	0.32	0.63	0.23	0.35	0.97

^{a b c} Means differ (P<0.05)

Table 3.7: Effect of sire line (S), slaughter weight endpoint (W), and gender (G) on proximate composition of longissimus trimmed of all external fat

Variable	Sire Line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction			
	LYL	MQL		113	136	159		M	F		S*G	S*W	W*G	S*W*G
Crude Protein, %	23.5	23.3	0.11	22.9 ^a	23.6 ^b	23.6 ^b	<0.01	23.3	23.5	0.04	0.12	0.05	0.98	0.06
Moisture, %	72.5	72.0	<0.01	72.3	72.2	72.3	0.54	72.2	72.3	0.65	0.55	0.25	0.79	0.68
Crude Fat, %	2.4	3.1 ^c	<0.01	3.0 ^a	2.7 ^{ab}	2.5 ^b	0.07	2.9	2.6	0.07	0.67	0.72	0.65	0.29

^{a b c} Means differ (P<0.05)

Table 3.8: Effect of sire line (S), slaughter weight endpoint (W), and gender (G) on Warner-Bratzler shear force of the Longissimus Dorsi

Variable	Sire Line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction			
	LYL	MQL		113	136	159		M	F		S*G	S*W	W*G	S*W*G
Frozen weight, g	176.9	169.2	0.03	148.4 ^a	175.8 ^b	195.1 ^c	<0.01	168.5	177.7	<0.01	0.36	0.68	0.37	0.79
Thaw weight, g	165.6	160.1	0.08	140.0 ^a	164.8 ^b	183.8 ^c	<0.01	158.8	166.9	0.01	0.37	0.62	0.29	0.76
Cook weight, g	142.4	138.3	0.14	121.8 ^a	141.3 ^b	158.1 ^c	<0.01	136.9	143.8	0.01	0.55	0.76	0.36	0.87
Initial temperature, °C	9.8	9.7	0.70	10.0	9.7	9.6	0.20	9.7	9.8	0.55	0.07	0.52	0.93	0.69
Final temperature, °C	66.8	66.5	0.41	66.7	66.9	66.4	0.39	66.8	66.6	0.56	0.96	0.52	0.04	0.33
Cook time, min	5.4	5.6	0.30	5.0 ^a	5.6 ^b	5.8 ^b	<0.01	5.5	5.5	0.78	0.05	0.56	0.59	0.51
Thaw loss, %	6.4	5.3	<0.01	5.7	6.1	5.7	0.40	5.7	6.0	0.28	0.87	0.64	0.83	0.96
Cook loss, %	13.9	13.6	0.51	13.0 ^a	14.3 ^b	13.9 ^{ab}	0.07	13.7	13.7	0.95	0.31	0.41	0.08	0.87
Total loss, %	19.4	18.2	0.03	17.9 ^a	19.5 ^b	18.8 ^{ab}	0.05	18.6	18.9	0.57	0.37	0.48	0.15	0.92
Degree of doneness	4.0	4.0	0.89	4.0	4.1	4.0	0.70	4.0	4.0	0.65	0.89	0.87	0.07	0.87
WBSF, kg	2.6	2.6	0.92	2.4 ^a	2.7 ^b	2.7 ^b	0.02	2.6	2.6	0.92	0.04	0.82	0.73	0.20

^{a b c} Means differ (P<0.05)

Table 3.9: Effect of sire line (S), slaughter weight endpoint (W), and gender (G) on slice shear force of the Longissimus Dorsi

Variable	Sire Line		Pr>F	Endpoint			Pr>F	Gender		Pr>F	Interaction			
	LYL	MQL		113	136	159		M	F		S*G	S*W	W*G	S*W*G
Frozen weight, g	178.6	168.0	<0.01	151.0 ^a	170.4 ^b	198.4 ^c	<0.01	171.5	175.1	0.35	0.37	0.34	0.83	0.17
Thaw weight, g	169.0	160.2	0.01	143.6 ^a	161.9 ^b	188.3 ^c	<0.01	163.4	165.8	0.50	0.40	0.34	0.85	0.11
Cook weight, g	145.9	137.2	<0.01	123.9 ^a	138.8 ^b	161.8 ^c	<0.01	139.9	143.1	0.28	0.24	0.19	0.79	0.10
Initial temperature, °C	10.9	10.7	0.52	10.8	10.8	10.8	0.98	10.8	10.8	0.93	0.99	0.30	0.22	0.60
Final temperature, °C	66.7	66.9	0.69	67.2 ^a	66.7 ^{ab}	66.5 ^b	0.11	66.6	66.9	0.30	0.13	0.87	0.94	0.31
Cook time, min	5.1	5.5	0.06	4.9 ^a	5.3 ^{ab}	5.7 ^b	<0.01	5.4	5.1	0.17	0.67	0.97	0.83	0.69
Thaw loss, %	5.3	4.6	0.01	4.8	4.9	5.0	0.69	4.6	5.2	0.01	0.39	0.75	0.42	0.37
Cook loss, %	13.7	14.3	0.19	13.8	14.2	14.0	0.77	14.4	13.6	0.12	0.26	0.56	0.45	0.86
Total loss, %	18.2	18.2	0.93	17.9	18.5	18.3	0.62	18.3	18.1	0.73	0.53	0.68	0.86	0.85
Degree of doneness	4.4	4.5	0.54	4.4	4.5	4.6	0.27	4.5	4.5	0.72	0.92	0.68	0.93	0.45
SSF, kg	15.0	15.6	0.18	14.3 ^a	16.1 ^b	15.6 ^b	<0.01	15.2	15.5	0.57	0.07	0.95	0.58	0.05

^{a b c} Means differ (P<0.05)

Table 3.10: Interaction of sire line and gender for % skinless ham, belly width (cm), Warner-Bratzler cook time (min), and Warner-Bratzler shear force (kg)

Variable	MQL F	MQL M	LYL F	LYL M
% Skinless Ham	21.7 ^a	20.9 ^b	22.3 ^c	22.3 ^c
Belly width, cm	28.3 ^a	28.5 ^{ab}	29.3 ^b	28.3 ^a
WB cook time, min	5.4 ^{ab}	5.7 ^a	5.6 ^{ab}	5.2 ^b
WBSF, kg	2.5	2.7	2.7	2.5

^{a b c} Means differ (P<0.05)

Table 3.11: Interaction of sire line and slaughter weight endpoint for loin 24-hour temperature (°C), belly dorsal firmness (cm), and % crude protein

Variable	MQL 113	MQL 136	MQL 159	LYL 113	LYL 136	LYL 159
Loin 24 hour temp, °C	-0.73 ^{cd}	-0.44 ^b	0.00 ^a	-0.79 ^d	-0.58 ^{bc}	-0.39 ^b
Dorsal firmness, cm	9.2 ^{ab}	11.5 ^c	15.1 ^d	8.0 ^a	11.0 ^{bc}	10.8 ^{bc}
% Crude protein	23.0 ^a	23.4 ^{ac}	23.4 ^{ac}	22.8 ^a	23.8 ^{cd}	23.9 ^d

^{a b c d} Means differ (P<0.05)

Table 3.12: Interaction of slaughter weight endpoint and gender for % inside ham and Warner-Bratzler final temperature (°C)

Variable	113 F	136 F	159 F	113 M	136 M	159 M
% Inside Ham	5.00 ^b	4.85 ^b	4.57 ^a	4.49 ^a	4.54 ^a	4.49 ^a
WB Final temp. °C	66.08 ^a	66.96 ^{ab}	66.71 ^{ab}	67.27 ^b	66.85 ^{ab}	66.13 ^a

^{a b} Means differ (P<0.05)

Table 3.13: Interaction of sire line, slaughter weight endpoint, and gender for Gluteus profundus L* and a* and slice shear force (kg)

Variable	MQL F	MQL F	MQL F	MQL M	MQL	MQL	LYL F	LYL F	LYL F	LYL M	LYL M	LYL M
	113 kg	136 kg	159 kg	113 kg	M	M	113 kg	136 kg	159 kg	113 kg	136 kg	159 kg
Gluteus Profundus L*	42.70 ^{ab}	42.00 ^{ab}	42.64 ^{ab}	42.02 ^{ab}	44.38 ^a	42.54 ^{ab}	38.29 ^c	41.67 ^{abc}	40.46 ^{bc}	41.80 ^{abc}	39.17 ^{bc}	40.52 ^{bc}
Gluteus Profundus a*	15.83 ^c	17.87 ^{ab}	16.75 ^{abc}	16.05 ^c	15.95 ^c	16.38 ^{abc}	16.54 ^{abc}	16.64 ^{abc}	17.48 ^{abc}	16.15 ^{bc}	18.09 ^a	16.94 ^{abc}
Slice Shear Force (kg)	13.94 ^{cd}	16.04 ^{abc}	16.10 ^{abc}	15.45 ^{abc}	16.59 ^{ab}	15.77 ^{abc}	15.18 ^{abc}	16.92 ^a	14.62 ^{bcd}	12.81 ^d	14.87 ^{abcd}	15.74 ^{abc}

^{a b c} Means differ (P<0.05)

CHAPTER 4

CONCLUSIONS

In the global marketplace there is a growing demand for animal protein products and pork plays a significant role in filling this demand. Because pork consumption makes up approximately 50 percent of the world's total daily meat protein intake and pork ranks first for global per capita meat consumption (U.S. Pork Manual, Today's Pork Industry; Davis and Lin, 2005), there will continue to be a need for producer-based research.

Although pork quality is determined by a combination of color, marbling, juiciness, and tenderness, the only quality difference noted between sire lines was an advantage in marbling in the MQL versus LYL and in barrows versus gilts. In contrast, yield advantages, except in the belly, were seen in LYL compared to MQL and gilts compared to barrows. It would appear that the majority of these differences in quality and yield are associated with a general increase in fat accretion across the major depots in the carcass (i.e., subcutaneous, intermuscular, and intramuscular). Due to these differences between sire lines and genders, continued research focusing on these effects at a constant slaughter weight endpoint could benefit the growing consumer demand for a better eating experience.

As expected, increasing slaughter weight increased the total weight of product; however, due to the increase in fat accretion as weight increased, the yields decreased at heavier weights. Belly quality advantages (thickness and firmness) were seen in MQL versus LYL and at heavier slaughter weight endpoints, but this improvement appeared to

be associated with increased fatness. Although slaughter endpoint weights reached greater levels than much of the literature, the effects of the increased slaughter weight and gender were generally consistent with previous observations. Future research at the genetic level should focus on producing sire lines that can excel, or at least meet minimum standards, for both yield and meat quality attributes.