RESEARCH REPORT
PORK QUALITY

**Title:** Determination of the correlation of loin quality parameters with fresh belly characteristics and fresh and processed ham quality, **NPB #14-221**

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**Date Submitted:** 1 February, 2016

**Industry Summary:**

One of the key challenges currently facing the pork industry is a lack of insight into the relationship between loin, belly, and ham quality. Most published research focuses on loin, belly, or ham quality independent of each other rather than a whole-carcass quality assessment. It is unclear whether pigs with high quality loins will yield high quality hams or bellies. Therefore, the primary objective of this research was to correlate fresh loin quality with fresh belly quality and fresh and processed ham quality.

Pigs (8,042 total) raised in eight different barns representing two different production focuses were used in this study. Producers of pigs in four of the barns employed production programs focused on lean growth of pigs. Producers of pigs in the other four barns employed production programs focused on carcass/meat quality. Approximately half of the pigs were raised during the hot months and slaughtered in July, August, and September. The other half were raised in the cold months and slaughtered in February and March. All pigs were raised in the Midwest US and slaughtered at one Midwestern plant. Identity of the carcasses were maintained throughout the slaughter process to allow for meat quality relationships of the loin, belly, fresh ham, and processed ham to be determined. In total, 7,684 carcasses were evaluated.

The following data were collected from approximately 100% of total carcass:

- Hot carcass weight
- Carcass composition (via Fat-O-Meater)
- Iodine value using a desktop NIR on fat collected near the clear plate
- Boneless loin evaluation of VISNIR prediction for slice shear force and marbling
- Subjective color, marbling, and firmness of boneless loins
- Ham primal weight
- Objective color evaluation of the gluteus medius and gluteus profundus muscle

The following data were collected on approximately 50% of all carcasses:

- Fresh belly primal weight
- Subjective belly firmness score
- Fresh belly dimensions (length, width, and thickness)
- Fresh boneless loin weight
- Ultimate loin pH
- Loin objective color

The following data were collected on approximately 10% of all carcasses:

- 30 min postmortem loin muscle pH
- Longissimus dorsi and semimembranosus muscle temperature decline
- Loin muscle slice shear force
- Loin muscle ultimate pH determination
- Boneless loin purge loss after a 20 day storage period
- Fatty acid profile determination using gas chromatography
- Ham processing characteristics

To determine the relationship among loin, belly, and ham quality, correlation coefficients were determined for the traits above. Significant correlations with a correlation coefficient greater than 0.6 are generally considered strong relationships, correlation coefficients between 0.3 and 0.6 are considered moderate, and correlation coefficients less than 0.3 are weak. Correlations among selected traits are presented in Table 1.
It is not surprising that heavier carcasses produce heavier loins, bellies, and hams. Additionally, the weight of each individual primal is strongly related with the weight of the other primal pieces. These correlations were among the strongest in the study. However, the relationships among quality of the loin and ham and loin and belly were weak. Along those same lines, belly firmness, an indicator of belly quality, was not indicative of cured ham color or processing yields. Overall, fresh loin quality was not related to fresh or processed ham quality. Though most academic research uses the loin as the indicator of whole carcass quality, these results indicate that drawing conclusions about quality of the ham or belly using the quality indicators of the loin can be misleading.

**Table 1**. Correlations among carcass and primal weights with meat quality characteristics of the loin, belly, and ham

| | HCW | Loin wt | Belly wt | Ham wt | Loin color (L*) | Loin ultimate pH | Loin SSF | Belly firmness | Fresh ham face color (L*) | Cured ham color (L*) |
|---|---|---|---|---|---|---|---|---|---|---|
| Loin wt | **0.723** | | | | | | | | | |
| Belly wt | **0.862** | **0.476** | | | | | | | | |
| Ham wt | **0.890** | **0.706** | **0.685** | | | | | | | |
| Loin color (L*) | **-0.099** | **-0.087** | **-0.103** | **-0.121** | | | | | | |
| Loin ultimate pH | **-0.111** | **-0.169** | **-0.051** | **-0.115** | **-0.470** | | | | | |
| Loin SSF | **-0.211** | -0.044 | **-0.264** | **-0.126** | 0.051 | **-0.263** | | | | |
| Belly firmness | **0.451** | **0.053** | **0.635** | **0.300** | -0.050 | 0.011 | | | | |
| Fresh ham face color (L*) | **-0.068** | **-0.059** | **-0.149** | **-0.172** | **0.329** | **-0.336** | 0.055 | | | |
| Cured ham color (L*) | 0.024 | 0.040 | 0.017 | 0.032 | **0.247** | **-0.220** | **0.163** | -0.047 | **0.161** | |
| Cured ham cooked yield | 0.029 | 0.015 | 0.009 | 0.031 | **-0.132** | 0.156 | -0.010 | -0.024 | **-0.150** | **-0.076** |

Another key objective of this project was to compare carcass quality of pigs raised during cold seasons to that of pigs raised during the hot seasons. This can be very challenging because there a number of variables, such as diet, that contribute to differences in quality during differing seasons. Even so, 4 barns of pigs raised during the hot season were compared with 4 barns of pigs raised during the cold season. **In these populations of pigs,** several differences in quality were detected between the seasons. It is important to realize conclusions are based on one set of pigs raised during the hot season and one set of pigs raised during the cold season. Pigs raised during the hot season (12.51 kg sliced shear force, SSF) were more tender ($P < 0.0001$) than pigs raised on the cold season (16.68 kg SSF). Pigs raised in the cold season had a greater percentage ($P < 0.0001$) of package purge loss and cook loss compared with pigs raised in the hot season, but ultimate pH between the 2 groups of pigs was only 0.05 units different. Subjective loin color was not different ($P = 0.37$) between the two sets of pigs. In general, the magnitude of the differences in quality between seasons is small, and it is unclear what specific factors (diet, temperature, carcass chilling rate, or others) contributed to these differences.

The third objective was to characterize variation of carcass characteristics of pigs raised in production systems focused on either maximizing lean growth or maximizing meat quality. Variability of several traits was attributed to sex, production focus, marketing group, and inherent variability of the pig itself. Over 25% of the variability in fat depth can be attributed to production focus. Production focus also attributed to 20% of the total variance in loin depth and 35% of the total variance in estimated carcass lean. This is understandable as pigs selected for lean growth were 3.1 mm leaner at the 10$^{th}$ rib and had 2.5 percentage units greater estimated lean than pigs selected for meat quality. Overall, the lack of difference in HCW between pigs selected for lean growth and pigs selected for meat quality demonstrates an ability to control variation in this trait by slaughtering pigs in a multiple marketing group system.

**Table 2.** Effects of production focus on carcass characteristics

| | Lean | Quality | SEM | P-value |
|---|---|---|---|---|
| HCW, kg | 95.65 | 94.03 | 3.46 | 0.75 |
| Back fat, mm | 14.30 | 17.40 | 1.47 | **0.02** |
| Loin depth, mm | 70.71 | 65.05 | 2.62 | **0.02** |
| Percent Lean, % | 58.62 | 56.08 | 1.11 | **<0.01** |

From these results, the following conclusions can be made:
1) Meat quality of the entire carcass is not synonymous with loin quality. Carcasses with high quality loins do not necessarily produce high quality bellies and hams. The give and take in quality among the primal components requires more intensive investigation including identifying factors that contribute to high quality bellies and hams.

2) Within this set of pigs, season of production does influence quality of pork carcasses. However, only limited conclusions about the direction and magnitude of those differences can be drawn from this study as only one instance of each season is present in the data.

3) While segregating pigs by marketing group or production focus may help to minimize uncertainty associated with total variation, variability in carcass traits still exists.

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**Keywords:** Belly, Correlation, Ham, Loin, Quality, Seasonality, Variation

**Scientific Abstract:**

The primary objective of this research was to characterize variability of the U.S. pork supply. To achieve the primary objective we had three primary goals: 1) correlate fresh loin quality with fresh belly characteristics and fresh and processed ham quality, 2) evaluate differences in loin, ham, and fresh belly quality from pigs marketed in cold and hot seasons, and 3) characterize variation in carcass characteristics of pigs selected to either maximize lean growth potential or maximize meat quality and marketed in three groups (cuts). Nearly 8,000 carcasses were evaluated in this study. Pigs were either raised with a production focus on lean growth or on exceptional meat quality and raised either during cold or hot seasons. Pigs from 8 total barns (2 from each production focus and season combination) in the Midwestern US were sold independently in 3 marketing groups from each barn based on visual appraisal of body weight with a target body weight based on each supplier's program specifications. All pigs were slaughtered under the supervision of FSIS in a single Midwestern plant. Pigs were immobilized using $CO_2$ stunning and slaughtered via exsanguination. Hot carcass weight was correlated with loin weight (r = 0.723; P < 0.05), belly weight (r = 0.862; P < 0.05), and ham weight (r = 0.890; P < 0.05). Loin weight was correlated with belly weight (r = 0.476; P < 0.05) and ham weight (r = 0.706; P < 0.05). Belly weight was correlated with ham weight (r = 0.685; P < 0.05). Even though carcass weights and primal weights were related, quality parameters from one primal often did not correlate (P > 0.05) with quality parameters of other primal pieces. Tenderness was weakly correlated (r = -0.263; P < 0.05) with loin ultimate pH. Cured ham color was weakly correlated with objective loin color (r = 0.247) and loin ultimate pH (r = -0.220). Overall, fresh loin quality is statistically but not meaningfully related to belly characteristics, fresh ham characteristics, or processed ham quality. Therefore, drawing conclusions about meat quality of the ham or belly using the quality indicators of the loin can be misleading. Comparisons of fresh and processed meat quality, as well as carcass composition, between pigs raised during the hot and cold seasons were made. Several statistical (P < 0.05) differences were detected, **however, season was not replicated and an additional replication would add credibility to the data.** Pigs raised during the cold season were 0.94 kg heavier (P < 0.0001), 1.08 mm leaner (P < 0.0001), had 4.68 mm larger loins (P < 0.0001), and had 1.22 percentage units greater (P < 0.0001) estimated lean values than pigs raised in the hot season. Ultimate pH of loins from pigs raised during the hot season were 0.05 units greater (P < 0.0001) than ultimate loin pH of pigs raised in the cold season. However, subjective color was not different (P = 0.37) and objective color was only 1.62 L* units greater (P < 0.0001) in pigs raised during the hot season compared with pigs raised during the cold season. Slice shear force values of pigs raised during the hot season were 4.17 kg more tender (P < 0.0001) than pigs raised during the cold season. Overall, differences in meat quality were detected between pigs raised during the cold season and pigs raised during the hot season, but **an additional replication is necessary before final conclusions can be made**. Contributions to total variance of carcass characteristics were determined for marketing group, sex, season, and production focus. The random effect of pig contributed the greatest proportion of total variance to carcass traits (93.5% of HCW, 51.2% of fat depth, 60.5% of loin depth, and 39.4% of percent lean). Marketing group contributed 4.1% and sex contributed 1.4% of the variation of HCW. Production focus contributed 26.7%, sex contributed to 17.6%, and season contributed 4.5% of the variation in fat depth. The remaining variation in loin depth was attributed to production focus (20.0%), season (16.1%), marketing group (2.0%), and sex (1.4%). Production focus (34.6%), sex (15.8%), and season (10.2%) were large contributors to total variation in percent lean. No difference in variability between sexes existed for HCW (P = 0.09) or loin depth (P = 0.60); barrows had greater variation than gilts for fat depth and percent lean (P ≤ 0.01). Variability was greater in the hot

season for HCW, but was less for fat depth and percent lean compared with the variability of HCW in pigs from the cold season ($P \leq 0.01$). The quality production focus had a greater variance than the lean focus for HCW, fat depth, and loin depth ($P \leq 0.03$). No difference in variability of marketing groups existed for loin depth ($P = 0.20$). A difference in variability among marketing groups exists for HCW, fat depth, and percent lean ($P \leq 0.01$).

**Introduction:**

Consumers of pork desire a consistently high quality eating experience. Therefore, the presence of extensive variation in fresh pork quality has the potential to result in pork products becoming less competitive for consumer dollars due to reduced consumer confidence in the predictability of finished product quality. Of importance, fresh pork quality is only evaluated at the packer level by a few companies, primarily because producers are not rewarded financially for supplying high quality product, nor are they penalized for supplying lower quality product. Moreover, most peer-reviewed literature centers on loin quality and essentially neglects the ham. This is especially troubling, because the loin is currently only the third most valuable primal on $/cwt basis. Despite its lower value, the ham comprises nearly 25% of the weight of a side of pork, and as such, its quality is an important consideration for overall pork quality. One of the key challenges currently facing the pork industry, therefore, is a current lack of insight into the relationship between loin and ham quality and loin and belly quality. The correlation between loin and ham quality is likely associated with inherent variation associated with the pigs themselves, uncontrollable seasonality effects (e.g. raising pigs in hot weather), and in-plant practices such as spray-chilling vs blast-chilling. Therefore, a *critical need* exists to determine the relationship between fresh loin quality with fresh and processed ham quality. Otherwise, alternative meat animal protein sources will likely gain a competitive advantage over pork, because of their ability to produce a more consistent product that may well have a greater consumer appeal.

The *long-term goal* in our research is to characterize variability of fresh loin quality, belly quality and fresh and processed ham quality in a commercial processing facility to aid in positioning pork as a center of the plate protein preference for consumers through increased consistency of pork products. Most published research focuses on loin, ham, or belly quality independent of each other rather than a whole-carcass quality assessment. Therefore, the PRIMARY objective of this research was to correlate fresh loin quality with fresh belly quality and fresh and processed ham quality. Our *central hypothesis* was that the relationship in relative quality of pork products is influenced by inherent variation among the pigs themselves, as well as variations in on-farm practices that will significantly contribute to pork quality variation observed in the plant. Our *rationale* for this research was that a more complete appreciation of whole-carcass quality relationships between loin, belly, and ham quality, regardless of external (production) factors, and the underlying reasons responsible for it, can be expected to provide producers with opportunities to develop strategies to minimize variation in overall carcass quality.

**Objectives:**

Correlate fresh loin quality parameters (muscle pH, color, and tenderness) with fresh belly characteristics and fresh and processed ham quality.

Evaluate the differences in loin, ham, and fresh belly quality from pigs marketed in cold and hot seasons.

Characterize variation in carcass characteristics of pigs selected either for high lean growth potential or for more desirable meat quality.

**Materials & Methods:**

Pigs (N = 8,042) raised in eight different barns representing two different production focuses were used in this study. Producers of barns A, C, E, and G had production programs focused on lean growth of pigs, while barns B, D, F, and H had programs focused on meat quality. In line with current industry procedures, pigs in barns A and C received ractopamine at 5.0 mg/kg (4.5 g/ton) during a portion of the time on feed (Table 1). Pigs were slaughtered over a 4 wk time period, within their respective seasons, where the first marketing group from barn A, B, E, and F were marketed during the first week. The initial marketing group from barn C, D, G, and H was during the second week. Pigs were marketed in subsequent weeks until all pigs were marketed (Table 2). This allowed for direct comparison of first marketing groups with second marketing groups and comparison of second marketing groups with third marketing groups in an attempt to control the variation caused by day of slaughter.

*Processing Facility data collection*

Lairage procedures followed normal plant operating procedures. Pigs selected for improved meat quality were held overnight at the plant (approximately 13 hours) and pigs selected for lean growth arrived at the plant approximately 7 hours prior to slaughter. All pigs were rendered insensible by carbon dioxide stunning and terminated via exsanguination. Immediately post evisceration, carcasses were assigned a sequence number on the shoulder and ham and each pig's respective lot tattoo was recorded. At approximately 30 minutes postmortem, loin pH was collected at approximately the 10$^{th}$ rib on 10% of the carcasses with a REED SD-230 meter (Wilmington, NC) fitted with a PHE-2385 glass combo electrode (Omega; Stamford, CT) during the first week and a FC 200 B series electrode (Hanna Instruments; Woonsocket, RI) for each of the remaining weeks. The entire population of carcasses were evaluated for iodine value (IV) using a NitFOM (Carometec A/S; Smorum, Denmak), HCW, fat depth and loin depth using a Fat-O-Meater probe (SFK Technology A/S; Herlev. Denmark) and an estimated percent lean was calculated using a plant proprietary equation. Carcasses were blast-chilled for approximately 90 min. After exiting the chiller, adipose tissue cores, approximately 3.81 cm in diameter, were collected from the left side of every carcasses from the clear plate. Adipose tissue cores were used to calculate iodine value using a Bruker MPA Multi-Purpose FT-NIR Analyzer (Bruker Optics, Billerica, MA, USA). Vertebrae of all loins and only bellies from the left side of odd numbered carcasses were labeled while carcasses hung in equilibration bays with sequence numbers consistent with both the ham and shoulder.

Approximately 22 h after exiting the blast chiller, carcasses were fabricated into primal. Bellies (NAMP #408) and hams (modified NAMP # 401) were collected and placed into combo bins for further analysis that same day. Loins were fabricated into Canadian back loins (NAMP #414). Fresh muscle color (1 – 6 subjective scale), marbling (1 – 10 subjective scale), and firmness (1 – 5 subjective scale) were evaluated using NPPC standards on-line (at the time of fabrication) by an industry professional with over 15 years of pork quality research (NPPC 1991; NPPC 1999). Further, VISNIR measurements were conducted online and a subset (approximately 50%) of the loins were placed in a combo for further data collection.

*Bellies* – Skin-on bellies (NAMP #408) were weighed and measurements of belly length, width, and scribe line (distance from the line of rib removal to the dorsal edge of the belly; measured at approximately the center of the belly from the anterior to posterior end) were recorded on approximately 50% of the bellies. Belly depth was reported at 25%, 50% and 75% of the distance from the anterior toward the posterior end. A mean belly depth was also recorded by averaging the three depth values. A subjective flop score of 0.5-5.0 in 0.5 unit increments was assigned to each belly. Bellies on the low end of the scale (0.5) were anchored using the characterization of a wet towel and the high end (5.0) was characterized as the rigidity of a piece of cardboard.

*Loins* – Approximately 50% of the entire population of loins was selected for further quality analysis and boneless primal weight. Objective L*, a*, and b* color evaluations were conducted using a Hunter Miniscan XE Plus colorimeter (Hunter Lab; Reston, VA) with a D65 light source, 10 ° observer, and 25-mm port. Ultimate pH was recorded using a pH meter; for data collected on week 1, a REED SD-230 meter (Wilmington, NC) fitted with a PHE-2385 glass combo electrode (Omega; Stamford, CT) was used. Ultimate pH data collected during weeks 2-8, was collected with a HI 98160 Microprocessor Logging pH/ORP Meter (Hanna Instruments, Woonsocket, RI). Loins of the selected 10% were vacuum-packaged for shipping to the USDA-ARS U.S. Meat Animal Research Center.

*Hams* – Whole ham primal weight was recorded and objective L*, a*, and b* measures were recorded on the gluteus medius and gluteus profundis (Konica Minolta CR-400 colorimeter; Minolta Camera Company, Osaka, Japan; D65 light source, 0˚ observer, 8 mm aperture).

*Selected Loins*

Loins were transported (-2°C) to the U.S.D.A. Meat Animal Research Center and aged (2 °C) until 20 d postmortem when two 2.54-cm chops were obtained. Fresh (never frozen) chops were cooked to a desired internal temperature of 71 °C and slice shear force (SSF) was measured using the procedures of Shackelford et al., 2004. The two SSF values were then averaged. A 2.54 – cm chop was used to measure pH and color, marbling, and firmness scores were assigned using the same evaluation procedures as described for in-plant evaluations. Aged pH was evaluated on week one using a REED SD-230 meter (Wilmington, NC) fitted with a PHE-2385 glass combo electrode (Omega; Stamford, CT) and for weeks 2-8 a FC 200 B series electrode (Hanna Instruments; Woonsocket, RI). Day 20 postmortem color was measured on a 2.54 – cm chop packaged in retail overwrap with 2 h of bloom time using a Hunter Miniscan XE Plus colorimeter (Hunter Lab; Reston, VA with an A illuminant, 10 ° observer, and 25-mm port).

*Selected Hams*

*Fabrication and Quality Characteristics* - Hams were transported in combos via refrigerated truck to the University of Illinois Meat Science Laboratory where they were fabricated. A modified NAMP #401 (rectus abdominus attached) was weighed trimmed similar to a NAMP #402 and weighed to obtain a trimmed weight. Hams were then separated into 5 pieces: inside ham (NAMP #402F), outside ham (NAMP #402E), knuckle (NAMP #402H), inner shank portion and light butt. Weights were recorded on all pieces. Identification of the inside, outside and knuckle was maintained; however, inner shank and light butt identification was not retained as they were not needed for further analysis. Objective L*, a*, and b* values (Konica Minolta CR-400 colorimeter; Minolta Camera Company, Osaka, Japan; D65 light source, 0˚ observer, 8 mm aperture) and ultimate pH (MPI pH meter; Meat Probes Inc., Topeka, KS; 2 point calibration at pH 4 and 7) were collected on the semimembranosus (blonde spot, medial side), adductor (proximal face), semitendinosus dark portion (proximal edge where the head of the femur was removed), semitendinosus light (medial edge of the distal end), biceps femoris (medial side), vastus lateralis (proximal edge), and rectus femoris (proximal face).

*Ham processing* - Each set of inside, outside, and knuckles originating from the same whole ham were stuffed into nylon nets and weighed to determine green weight for the production of a NAMP #401G ham. Hams were injected with a multi-needle injector using a Schroder Injector Marinator model N50 (Wolf-Tec Inc., Kingston, NY) with a cure solution to a target of 120% of original green weight. Cure was formulated to include 1.52% salt, 0.33% sodium tripolyphosphate, 0.014% sodium nitrite, and 0.05% sodium erythorbate in the finished product. After injection, hams were immediately weighed to determine percent cure uptake. Hams were then allowed to drain for 30 minutes on smokehouse racks placed on a stainless steel table and hams were again weighed to determine final pump uptake, and final pumped weight. Percent uptake (both initial and final) were calculated as [(pumped weight – green weight) / green weight] * 100. Hams were allowed to equilibrate for at least two hours.

After this time, hams were removed from the nylon net, macerated twice, placed in a plastic bag (as a complete set of inside, outside, and knuckle originating from the same ham) and tumbled under a vacuum for two hours. After tumbling, ham pieces were stuffed into stuffing nets such that the outside portion was on the bottom of the ham, the inside portion was placed on top of the outside portion and the knuckle was placed in front of the inside and outside portions towards the factory clipped end of the netting. Hams were weighed to determine stuffed weight. Stuffed yield was calculated as (stuffed weight/green weight) * 100. Hams were cooked in an Alkar smokehouse (Lodi, WI) for 10 h to a targeted internal temperature of 65.6 °C. After cooking, hams were showered with cold water and moved to a 4 °C cooler where they were chilled for at least 24 h. Hams were weighed with both the casing on and the casing removed to determine a final cooked weight. Final cook yield was calculated as (casing off cooked weight/green weight) * 100.

*Cured Ham Color* - A 2.54-cm ham steak was cut using a deli slicer approximately 75% of the distance from the factory clipped end of the ham such that no portion of the knuckle was visible in the steak. Objective L*, a*, and b* measures (Konica Minolta CR-400 colorimeter; Minolta Camera Company, Osaka, Japan; D65 light source, 0˚ observer, 8 mm aperture) were collected in the fresh cut surface of the further processed ham. The ham was visually divided into 4 quadrants by dividing the ham in half both vertically and horizontally, and a color measurement was recorded in each quadrant. Reported values are the average of the 4 measurements. Ham steaks were vacuum packaged and frozen at -20 °C.

*Binding Strength* – Ham steaks used in cured ham color analysis were thawed at 4 °C for 24 hours. A standardized sample was prepared by cutting the sample 7.62-cm wide perpendicular to the seam of the inside and outside muscles of the ham steak. The steak was broken with constant force applied across the seam using a Texture Analyzer TA.HD Plus (Texture Technologies Corp., Scarsdale, NY/Stable Microsystems, Godalming, UK). Samples were broken with a 10-mm-diameter crossbar at a crosshead speed of 3.33 mm/s on a 3.81 cm platform and a 70 mm travel distance. The force necessary to break the bind is reported in kg.

*Statistical Analyses*

Data were analyzed using three approaches. Pearson correlation coefficients were computed using the correlation procedure of SAS (v.9.4, SAS Institute Inc., Cary, NC) for objective 1. A one-way analysis of variance was calculated to determine differences in quality traits of pigs slaughtered during cold seasons and hot seasons for objective 2. Season of slaughter was a fixed effect in the model and random effects included sex of the pig, marketing group, and selection focus. Separation of least square means was conducted using a Tukey's adjustment. Probability values were calculated using a two sided test with a significant difference at $P \leq 0.05$ and a tendency between $P > 0.05$ and $P \leq 0.10$. Proportion of total variance contributed by sex of the pig, marketing group, selection focus, and seasonality were calculated using the varcomp procedure of SAS for objective 3. The varcomp procedure estimates each independent variable's contribution to the variance of the dependent variable. The MIVQUE0 method for estimation of estimated mean squares was used.

**Results:**

The following tables (Tables 1-5) provide summary information regarding the population of pigs used in this study.

**Table 1.** Characterization of barns used in this study

| Barn | Selection Focus | Approx. Age, d | Time on ractopamine, d |
|---|---|---|---|
| A | Lean | | |
| Cut 1 | | 140 | 2 |
| Cut 2 | | 153 | 15 |
| Cut 3 | | 168 | 29 |
| B | Quality | | |
| Cut 1 | | 168 | 0 |
| Cut 2 | | 182 | 0 |
| Cut 3 | | 196 | 0 |
| C | Lean | | |
| Cut 1 | | 183 | 0 |
| Cut 2 | | 197 | 2 |
| Cut 3 | | 211 | 16 |
| D | Quality | | |
| Cut 1 | | 165 | 0 |
| Cut 2 | | 179 | 0 |
| Cut 3 | | 193 | 0 |
| E | Lean | | |
| Cut 1 | | 187 | 0 |
| Cut 2 | | 200 | 0 |
| Cut 3 | | 214 | 0 |
| F | Quality | | |
| Cut 1 | | 136 | 0 |
| Cut 2 | | 150 | 0 |
| Cut 3 | | 164 | 0 |
| G | Lean | | |
| Cut 1 | | 184 | 0 |
| Cut 2 | | 198 | 0 |
| Cut 3 | | 212 | 0 |
| H | Quality | | |
| Cut 1 | | 176 | 0 |
| Cut 2 | | 190 | 0 |
| Cut 3 | | 204 | 0 |

**Table 2.** Slaughter Schedule of Marketing Groups

| | Cold Season | | | | Hot Season | | | |
|---|---|---|---|---|---|---|---|---|
| | Barn A | Barn B | Barn C | Barn D | Barn E | Barn F | Barn G | Barn H |
| Week 1 | Cut 1 | Cut 1 | - - | - - | Cut 1 | Cut 1 | - - | - - |
| Week 2 | Cut 2 | Cut 2 | Cut 1 | Cut 1 | Cut 2 | Cut 2 | Cut 1 | Cut 1 |
| Week 3 | Cut 3 | Cut 3 | Cut 2 | Cut 2 | Cut 3 | Cut 3 | Cut 2 | Cut 2 |
| Week 4 | - - | - - | Cut 3 | Cut 3 | - - | - - | Cut 3 | Cut 3 |

**Table 3.** Population summary statistics of the carcass and fatty acid profiles

| Variable | N | Mean | Std Dev | Minimum | Maximum | CV |
|---|---|---|---|---|---|---|
| Total Observations | 7684 | -- | -- | -- | -- | -- |
| Carcass Composition | | | | | | |
| HCW, kg | 7576 | 94.50 | 9.39 | 53.06 | 129.25 | 9.93 |
| BF, mm | 6920 | 15.41 | 4.00 | 6.00 | 38.00 | 25.93 |
| LD, mm | 6920 | 68.00 | 8.52 | 20.00 | 92.00 | 12.53 |
| Percent Lean | 6920 | 57.63 | 2.76 | 42.50 | 65.20 | 4.79 |
| FAME Profile | | | | | | |
| Bruker measured IV | 7662 | 75.82 | 3.56 | 64.19 | 89.26 | 4.69 |
| NitFOM measured IV | 5625 | 74.44 | 3.42 | 63.90 | 92.50 | 4.60 |
| GC measured IV (AOACS) | 848 | 75.78 | 3.63 | 66.50 | 85.90 | 4.79 |

**Table 4.** Population summary statistics of the loin and belly

| Variable | N | Mean | Std Dev | Minimum | Maximum | CV |
|---|---|---|---|---|---|---|
| Loin Quality | | | | | | |
| Weight, kg | 3973 | 3.75 | 0.49 | 1.71 | 5.45 | 13.07 |
| pH, 30 min | 774 | 6.55 | 0.20 | 5.68 | 7.07 | 3.08 |
| pH, 24 h | 3990 | 5.69 | 0.15 | 5.37 | 6.79 | 2.56 |
| pH, 20 d | 818 | 5.68 | 0.17 | 5.34 | 7.00 | 3.01 |
| Color, 1 d | 7381 | 3.09 | 0.56 | 1.00 | 5.00 | 18.27 |
| Marbling, 1 d | 7381 | 2.13 | 0.92 | 0.50 | 6.00 | 43.35 |
| Firmness, 1 d | 7381 | 2.75 | 0.62 | 1.00 | 5.00 | 22.49 |
| Color, 20 d | 818 | 3.13 | 0.59 | 2.00 | 6.00 | 18.83 |
| Marbling, 20 d | 818 | 1.58 | 0.35 | 1.00 | 4.00 | 21.89 |
| Firmness, 20 d | 818 | 2.99 | 0.16 | 2.00 | 4.00 | 5.32 |
| 1 d | | | | | | |
| L* | 3937 | 52.66 | 2.49 | 44.30 | 62.05 | 4.73 |
| a* | 3937 | 7.40 | 1.15 | 2.94 | 11.41 | 15.55 |
| b* | 3937 | 13.64 | 1.04 | 9.92 | 17.63 | 7.61 |
| 20d | | | | | | |
| L* | 818 | 58.93 | 2.64 | 48.85 | 66.84 | 4.48 |
| a* | 818 | 10.06 | 1.40 | 4.77 | 15.22 | 13.88 |
| b* | 818 | 17.12 | 1.02 | 13.40 | 21.74 | 5.96 |
| Purge loss (%), 20 d | 805 | 0.92 | 0.62 | 0.00 | 4.71 | 67.39 |
| Cook loss (%), d 20 | 818 | 17.28 | 2.01 | 8.40 | 23.15 | 11.64 |
| VISNIR | 7377 | 0.32 | 0.04 | 0.21 | 0.54 | 11.76 |
| VISNIR predicted SSF | 7377 | 17.25 | 1.86 | 6.54 | 22.74 | 10.76 |
| SSF | 818 | 14.80 | 5.50 | 5.90 | 39.51 | 37.16 |
| Belly Quality | | | | | | |
| Weight, kg | 3648 | 7.43 | 1.15 | 3.68 | 12.64 | 15.48 |
| Flop Score | 3646 | 2.05 | 0.84 | 0.50 | 5.00 | 40.95 |
| Length, cm | 3648 | 69.24 | 4.31 | 52.71 | 84.46 | 6.23 |
| Width, cm | 3647 | 35.91 | 2.45 | 27.31 | 44.45 | 6.81 |
| Scribe, cm | 3638 | 7.33 | 1.35 | 1.27 | 13.34 | 18.41 |
| Depth, 25%, cm | 3648 | 2.81 | 0.55 | 0.64 | 4.76 | 19.44 |
| Depth, 50%, cm | 3646 | 2.21 | 0.45 | 0.00 | 3.81 | 20.45 |
| Depth, 75%, cm | 3647 | 2.56 | 0.45 | 1.27 | 4.76 | 17.54 |
| Average Depth, cm | 3648 | 2.53 | 0.42 | 0.85 | 4.02 | 16.59 |

**Table 5.** Population summary statistics of the ham

| Variable | N | Mean | Std Dev | Minimum | Maximum | CV |
|---|---|---|---|---|---|---|
| Fresh Ham Quality | | | | | | |
| Weight, 1 d, kg | 7539 | 11.74 | 1.10 | 6.89 | 15.60 | 9.33 |
| Inside weight, kg | 838 | 1.64 | 0.23 | 0.45 | 2.71 | 14.21 |
| Outside weight, kg | 845 | 2.24 | 0.31 | 1.12 | 3.21 | 13.95 |
| Knuckle weight, kg | 845 | 1.33 | 0.17 | 0.72 | 1.79 | 12.66 |
| Shank weight, kg | 845 | 0.69 | 0.10 | 0.40 | 1.69 | 14.95 |
| Light butt weight, kg | 843 | 0.35 | 0.09 | 0.08 | 0.72 | 25.71 |
| Gluteus profundis L* | 7418 | 40.60 | 3.61 | 22.88 | 56.98 | 8.89 |
| Gluteus medius L* | 7422 | 45.69 | 3.37 | 20.64 | 68.04 | 7.38 |
| Semimembranosus L* | 840 | 46.57 | 3.14 | 36.38 | 62.33 | 6.73 |
| Adductor L* | 841 | 39.28 | 3.11 | 30.09 | 55.00 | 7.91 |
| Semitendinosus, Light L* | 840 | 52.08 | 6.12 | 35.72 | 73.20 | 11.75 |
| Semitendinosus, Dark L* | 839 | 40.09 | 3.32 | 31.41 | 55.92 | 8.29 |
| Biceps femoris L* | 840 | 43.93 | 3.04 | 35.15 | 55.52 | 6.92 |
| Vastus lateralis L* | 841 | 46.48 | 3.21 | 33.87 | 59.64 | 6.91 |
| Rectus femoris L* | 841 | 45.39 | 3.35 | 34.25 | 56.09 | 7.38 |
| pH | | | | | | |
| Semimembranosus | 842 | 5.66 | 0.28 | 4.68 | 7.07 | 4.97 |
| Adductor | 843 | 5.80 | 0.29 | 4.81 | 7.08 | 4.98 |
| Semitendinosus, Light | 842 | 5.77 | 0.28 | 4.47 | 6.91 | 4.82 |
| Semitendinosus, Dark | 842 | 5.87 | 0.30 | 4.85 | 6.77 | 5.14 |
| Biceps femoris | 843 | 5.68 | 0.27 | 4.79 | 7.05 | 4.82 |
| Vastus lateralis | 843 | 5.73 | 0.28 | 4.77 | 7.04 | 4.95 |
| Rectus femoris | 843 | 6.04 | 0.33 | 5.01 | 7.07 | 5.41 |
| Cured Ham Quality | | | | | | |
| Green weight, kg | 840 | 5.10 | 0.61 | 2.77 | 7.05 | 11.99 |
| Pumped weight, kg | 844 | 6.12 | 0.76 | 3.37 | 8.81 | 12.33 |
| Pump percent, % | 840 | 19.97 | 4.04 | 7.71 | 43.85 | 20.21 |
| 30 minute drained weight, kg | 844 | 5.97 | 0.73 | 3.28 | 8.38 | 12.26 |
| Pump uptake, % | 840 | 16.87 | 3.27 | 6.69 | 36.44 | 19.41 |
| Stuffed weight, kg | 830 | 5.77 | 0.69 | 3.22 | 7.97 | 11.94 |
| Stuffed yield, % | 824 | 113.06 | 3.76 | 77.21 | 168.80 | 3.32 |
| Casing on cooked weight, kg | 829 | 5.13 | 0.65 | 2.81 | 7.15 | 12.61 |
| Casing off cooked weight, kg | 829 | 5.07 | 0.65 | 2.74 | 7.09 | 12.76 |
| Cooked yield, % | 823 | 99.33 | 4.07 | 67.90 | 149.63 | 4.09 |
| Cured color L* | 823 | 65.97 | 2.72 | 55.93 | 75.53 | 4.13 |
| Bind strength, kg | 792 | 7.76 | 1.99 | 2.62 | 17.39 | 25.70 |
| Proximate Composition | | | | | | |
| Moisture, % | 829 | 72.74 | 1.45 | 67.33 | 78.57 | 2.00 |
| Lipid, % | 829 | 5.03 | 1.58 | 1.75 | 13.41 | 31.50 |

**Objective 1 - Correlate fresh loin quality parameters (muscle pH, color, and tenderness) with fresh belly characteristics and fresh and processed ham quality.**

Statistically significant (P ≤ 0.05) relationships were determined for the loin with the belly, fresh ham, and cured ham; however, those relationships were weak. As expected, loin weight was related to belly (r = 0.476; P < 0.0001) and fresh ham weight (r = 0.706; P < 0.0001). However, other than weights, few loin quality traits were meaningfully (r > 0.30) related with fresh belly characteristics. Loin weight and belly width were positively related (r = 0.37; P < 0.0001). As marbling increased in these populations of pigs, belly flop distance also increased (r = 0.337; P < 0.0001). In other words, as marbling of the loin increased, bellies became firmer. As slice shear force increased in these populations of pigs, belly flop distance decreased (r = -0.348; P < 0.0001). In other words, as loins became more tender, bellies became firmer.

**Table 1**. Pearson correlation coefficients of fresh loin characteristics with fresh belly characteristics

| | Belly wt | Flop Score | Length | Width | Thickness |
|---|---|---|---|---|---|
| Loin wt | **0.476** | **0.053** | **0.213** | **0.37** | **0.24** |
| | <0.0001 | <0.01 | <0.0001 | <0.0001 | <0.0001 |
| pH, 30 min | **-0.081** | **-0.085** | **-0.173** | **0.097** | -0.051 |
| | 0.03 | 0.02 | <0.0001 | 0.01 | 0.16 |
| pH, 24 h | **-0.051** | 0.011 | **0.141** | **-0.197** | **-0.07** |
| | <0.01 | 0.51 | <0.0001 | <0.0001 | <0.0001 |
| Color | **0.146** | **0.203** | **0.238** | **-0.076** | **0.126** |
| | <0.0001 | <1.0001 | <0.0001 | <0.0001 | <0.0001 |
| Marbling | **0.136** | **0.337** | **0.217** | -0.024 | **0.191** |
| | <0.0001 | <0.0001 | <0.0001 | 0.15 | <0.0001 |
| Firmness | **0.15** | **0.253** | **0.049** | 0.029 | **0.177** |
| | <0.0001 | <0.0001 | <0.01 | 0.08 | <0.0001 |
| L* | -0.021 | **0.097** | 0.031 | **-0.074** | 0.025 |
| | 0.23 | <0.0001 | 0.07 | <0.0001 | 0.14 |
| a* | **0.136** | **0.166** | 0.031 | **0.087** | **0.200** |
| | <0.0001 | <0.0001 | 0.07 | <0.0001 | <0.0001 |
| b* | **0.137** | **0.219** | **0.086** | -0.003 | **0.197** |
| | <0.0001 | <0.0001 | <0.0001 | 0.86 | <0.0001 |
| Purge loss, 20d | **-0.145** | **-0.224** | **-0.251** | **0.147** | **-0.141** |
| | <0.0001 | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Cook loss, 20d | **-0.263** | **-0.197** | **-0.16** | 0.001 | **-0.199** |
| | <0.0001 | <0.0001 | <0.0001 | 0.98 | <0.0001 |
| SSF[1] | **-0.264** | **-0.348** | **-0.193** | 0.031 | **-0.287** |
| | <0.0001 | <0.0001 | <0.0001 | 0.38 | <0.0001 |

[1]SSF = Slice shear force

Similar to the belly, loin weight was correlated with ham weight (r = 0.706; P < 0.000). Gluteus medius L* was moderately (r > 0.30) correlated with loin ultimate pH (r = -0.336; P < 0.0001) and loin L* (r = 0.329; P < 0.0001). In other words, as loin pH approached the isoelectric point of muscle, ham face color became lighter. Also, as ham face (gluteus medius) color became lighter, loin color also became lighter.

**Table 2**. Pearson correlation coefficients of fresh loin characteristics with fresh ham characteristics

| | | Gluteus medius | | |
|---|---|---|---|---|
| | Ham wt | L* | a* | b* |
| Loin wt | **0.706** | **-0.059** | **0.038** | **0.074** |
| | <0.0001 | <0.01 | 0.02 | <0.0001 |
| pH, 30 min | -0.037 | -0.03 | 0.041 | **0.106** |
| | 0.31 | 0.41 | 0.27 | <0.01 |
| pH, 24 h | **-0.115** | **-0.336** | **-0.084** | **-0.251** |
| | <0.0001 | <0.0001 | <0.0001 | <0.0001 |
| Color | -0.006 | **-0.287** | **0.104** | **-0.065** |
| | 0.62 | <0.0001 | <0.0001 | <0.0001 |
| Marbling | **-0.12** | -0.004 | **0.072** | **0.036** |
| | <0.0001 | 0.75 | <0.0001 | <0.01 |
| Firmness | **0.152** | **-0.119** | **0.052** | -0.023 |
| | <0.0001 | <0.0001 | <0.0001 | 0.06 |
| L* | **-0.125** | **0.329** | **-0.194** | **0.041** |
| | <0.0001 | <0.0001 | <0.0001 | 0.01 |
| a* | **0.037** | **-0.06** | **0.272** | **0.178** |
| | 0.02 | <0.01 | <0.0001 | <0.0001 |
| b* | -0.003 | **0.22** | **-0.044** | **0.119** |
| | 0.85 | <0.0001 | 0.01 | <0.0001 |
| Purge loss, 20d | 0.017 | **0.135** | 0.048 | **0.151** |
| | 0.63 | <0.01 | 0.18 | <0.0001 |
| Cook loss, 20d | **-0.187** | **0.231** | 0.025 | **0.191** |
| | <0.0001 | <0.0001 | 0.48 | <0.0001 |
| SSF[1] | **-0.126** | 0.055 | 0.037 | **0.136** |
| | <0.01 | 0.12 | 0.3 | <0.01 |

[1]SSF = Slice shear force

Loin weight was correlated with fabricated ham green weight ($r = 0.691$; $P < 0.0001$) and fabricated ham pumped weight ($r = 0.660$; $P < 0.0001$). No other fresh loin traits were related ($r > 0.30$) to cured ham quality except a* values. As fresh loin a* increased (loins became more red), a* values of cured hams also became more red ($r = 0.331$; $P < 0.0001$).

**Table 3**. Pearson correlation coefficients of fresh loin characteristics with cured ham characteristics

| | Green wt | Pumped wt | Uptake percentage | Cooked yield | Cured color L* | Cured color a* | Cured color b* |
|---|---|---|---|---|---|---|---|
| Loin wt | **0.691**<br><0.0001 | **0.660**<br><0.0001 | -0.028<br>0.43 | 0.015<br>0.68 | 0.04<br>0.26 | 0.036<br>0.31 | 0.013<br>0.71 |
| pH, 30 min | 0.02<br>0.57 | 0.028<br>0.44 | 0.02<br>0.59 | 0.052<br>0.15 | **0.207**<br><0.0001 | 0.058<br>0.11 | -0.04<br>0.28 |
| pH, 24 h | -0.058<br>0.1 | -0.042<br>0.23 | **0.087**<br>0.01 | **0.156**<br><0.0001 | **-0.22**<br><0.0001 | -0.019<br>0.59 | **-0.25**<br><0.0001 |
| Color | **-0.092**<br>0.01 | -0.073<br>0.04 | 0.062<br>0.08 | **0.138**<br><0.0001 | **-0.222**<br><0.0001 | **0.141**<br><0.0001 | -0.015<br>0.67 |
| Marbling | **-0.29**<br><0.0001 | **-0.282**<br><0.0001 | -0.007<br>0.85 | **0.091**<br>0.01 | -0.005<br>0.90 | -0.032<br>0.36 | -0.031<br>0.38 |
| Firmness | 0.059<br>0.09 | 0.045<br>0.20 | -0.041<br>0.24 | 0.032<br>0.36 | -0.019<br>0.60 | 0.003<br>0.93 | -0.009<br>0.81 |
| L* | **-0.187**<br><0.0001 | **-0.185**<br><0.0001 | -0.006<br>0.87 | **-0.135**<br><0.01 | **0.111**<br><0.01 | **-0.279**<br><0.0001 | **0.088**<br>0.01 |
| a* | **-0.085**<br>0.02 | **-0.093**<br>0.01 | -0.051<br>0.15 | 0.059<br>0.1 | **-0.088**<br>0.01 | **0.331**<br><0.0001 | **0.155**<br><0.0001 |
| b* | **-0.137**<br><0.01 | **-0.136**<br><0.01 | -0.004<br>0.92 | **-0.098**<br>0.01 | -0.01<br>0.78 | **-0.127**<br><0.01 | **0.176**<br><0.0001 |
| Purge loss, 20d | **0.127**<br><0.01 | **0.103**<br><0.01 | **-0.109**<br><0.01 | **-0.113**<br><0.01 | **0.179**<br><0.0001 | 0.031<br>0.38 | **0.071**<br>0.05 |
| Cook loss, 20d | **-0.117**<br><0.01 | **-0.116**<br><0.01 | -0.053<br>0.13 | **-0.109**<br><0.01 | **0.196**<br><0.0001 | 0.035<br>0.33 | **0.154**<br><0.0001 |
| SSF[1] | -0.008<br>0.83 | 0.002<br>0.95 | -0.006<br>0.86 | -0.01<br>0.77 | **0.163**<br><0.0001 | 0.03<br>0.4 | -0.056<br>0.12 |

[1]SSF = Slice shear force

**Objective 2 - Evaluate the differences in loin, ham, and fresh belly quality from pigs marketed in cold and hot seasons.**

Pigs slaughtered in the cold season produced carcasses that were 0.94 kg heavier (P < 0.0001), 1.08 mm leaner at the 10th rib (P < 0.0001), and had 4.68 greater loin depths (P < 0.0001) than pigs slaughtered in the hot season (Table 1). This resulted in a 1.22 percentage unit advantage (P < 0.0001) in estimated carcass lean of pigs slaughtered in the cold season compared with pigs slaughtered in the hot season.

Several differences in loin quality parameters were detected in pigs slaughtered in the cold season compared with pigs in the hot season. Loins from pigs slaughtered in the cold season were heavier and had greater 30 min postmortem muscle pH values, but lower 24 h and 20 d postmortem muscle pH values compared with pigs slaughtered in the hot season (Table 2). Subjective color evaluations were the same (P = 0.37) for pigs slaughtered in the cold season and pigs slaughtered in the hot season. However, pigs slaughtered in the cold season produced loins that had more visible marbling and were firmer to the touch compared with pigs slaughtered in the hot season.

**Table 1.** Effect of seasonality on carcass characteristics

| | Season | | | |
|---|---|---|---|---|
| | Cold | Hot | SEM | P-values |
| HCW, kg | 95.02 | 94.08 | 1.26 | <0.0001 |
| Back fat, mm | 15.12 | 16.20 | 2.09 | <0.0001 |
| Loin depth, mm | 70.22 | 65.54 | 2.78 | <0.0001 |
| Estimated carcass lean, % | 58.07 | 56.85 | 1.57 | <0.0001 |
| [1]Bruker IV | 75.87 | 75.59 | 1.73 | <0.0001 |
| NitFOM IV | 74.67 | 73.34 | 1.70 | <0.0001 |
| [1]AOCS IV | 75.54 | 75.93 | 1.50 | 0.09 |

[1]Fat sample collected near the midline of the dorsal edge of the shoulder

By d 20 postmortem, differences in firmness had diminished and were no longer different. Overall water capacity was better in pigs slaughtered in the hot season compared with pigs slaughtered in the cold season. Pigs slaughtered in the cold season had 0.41 percentage units greater purge loss and 1.41 percentage units greater cook loss values compared with pigs slaughtered in the hot season. Additionally, pigs slaughtered in the cold season were less tender than pigs slaughtered in the hot season and had 4.17 kg greater ($P < 0.0001$) slice shear force values (Table 2).

**Table 2.** Effect of seasonality on fresh loin quality

| | Season | | | |
|---|---|---|---|---|
| | Cold | Hot | SEM | P-values |
| Loin Weight, kg | 3.78 | 3.69 | 0.18 | <0.0001 |
| pH, 30 min | 6.61 | 6.50 | 0.04 | <0.0001 |
| pH, 24 h | 5.67 | 5.72 | 0.02 | <0.0001 |
| pH, 20 d | 5.64 | 5.75 | 0.05 | <0.0001 |
| Color, 1 d | 3.07 | 3.08 | 0.22 | 0.37 |
| Marbling, 1 d | 2.18 | 2.06 | 0.52 | <0.0001 |
| Firmness, 1 d | 2.77 | 2.71 | 0.14 | <0.01 |
| Color, 20 d | 3.10 | 3.16 | 0.09 | 0.14 |
| Marbling, 20 d | 1.54 | 1.66 | 0.15 | <0.0001 |
| Firmness, 20 d | 2.99 | 3.00 | 0.02 | 0.39 |
| 1 d | | | | |
| L* | 52.00 | 53.62 | 0.63 | <0.0001 |
| a* | 7.68 | 7.00 | 0.15 | <0.0001 |
| b* | 13.35 | 14.10 | 0.19 | <0.0001 |
| 20d | | | | |
| L* | 58.62 | 59.31 | 0.35 | <0.01 |
| a* | 10.45 | 9.52 | 0.22 | <0.0001 |
| b* | 17.00 | 17.21 | 0.22 | <0.01 |
| Purge loss, %, 20 d | 1.10 | 0.69 | 0.24 | <0.0001 |
| Cook loss, %, d 20 | 17.90 | 16.49 | 0.20 | <0.0001 |
| VISNIR predicted SSF, kg | 17.44 | 17.02 | 0.73 | <0.0001 |
| Slice shear force, kg | 16.68 | 12.51 | 1.59 | <0.0001 |

Similar to the loin, several differences in fresh ham quality were also observed. Primal ham weights from pigs slaughtered in the cold were heavier (P < 0.0001) than primal ham weights of pigs slaughtered in the hot season (Table 3). In addition to the primal ham being heavier, all ham component weights were heavier (P < 0.0001) in pigs slaughtered in the cold season compared with pigs slaughtered in the hot season. Ultimate muscle pH was less in the semimembranosus, adductor, semitendinosus, biceps femoris, vastus lateralis, and rectus femoris of pigs slaughtered in the cod season compared with pigs slaughtered in the hot season. There were no differences (P = 0.85) in the lightness (L*) of the gluteus profundis portion of the ham face, but the gluteus medius of pigs slaughtered in the cold season was 0.42 L* units less (darker) compared with L* values of the gluteus medius from pigs slaughtered in the hot season.

**Table 3.** Effect of seasonality on fresh ham quality

| | Season | | | |
|---|---|---|---|---|
| | Cold | Hot | SEM | P-values |
| Primal weight, kg | 11.79 | 11.66 | 0.14 | <0.0001 |
| Pre-trim weight, kg | 11.68 | 11.60 | 0.17 | 0.27 |
| Post-trim weight, kg | 9.82 | 9.76 | 0.24 | 0.36 |
| Inside weight, kg | 1.67 | 1.60 | 0.07 | <0.0001 |
| Outside weight, kg | 2.30 | 2.15 | 0.07 | <0.0001 |
| Knuckle weight, kg | 1.35 | 1.30 | 0.04 | <0.0001 |
| Shank weight, kg | 0.70 | 0.68 | 0.01 | <0.0001 |
| Light butt weight, kg | 0.36 | 0.34 | 0.02 | <0.0001 |
| Ultimate muscle pH | | | | |
| Semimembranosus | 5.62 | 5.72 | 0.04 | <0.0001 |
| Adductor | 5.74 | 5.87 | 0.04 | <0.0001 |
| Semitendinosus, Light | 5.73 | 5.81 | 0.03 | <0.0001 |
| Semitendinosus, Dark | 5.79 | 5.95 | 0.02 | <0.0001 |
| Biceps femoris | 5.64 | 5.74 | 0.03 | <0.0001 |
| Vastus lateralis | 5.69 | 5.78 | 0.02 | <0.0001 |
| Rectus femoris | 6.01 | 6.09 | 0.04 | <0.01 |
| Ham face color | | | | |
| Gluteus profundis | | | | |
| L* | 40.62 | 40.60 | 0.41 | 0.85 |
| a* | 15.71 | 15.87 | 0.10 | <0.01 |
| b* | 3.94 | 3.47 | 0.15 | <0.0001 |
| Gluteus medius | | | | |
| L* | 45.49 | 45.91 | 0.35 | <0.0001 |
| a* | 9.50 | 8.65 | 0.13 | <0.0001 |
| b* | 2.67 | 1.99 | 0.12 | <0.0001 |

The heavier ham primal weights and ham component weights from pigs slaughtered in the cold season resulted in heavier three-piece ham (IMPS #403G) green weights (P < 0.01) compared with green weights of pigs slaughtered in the hot season (Table 4). Despite a lesser (P < 0.01) pump uptake of hams from pigs slaughtered in the cold season compared with hams from pigs slaughtered in the hot season, cooked weights and overall cooked yield was greater (Table 4). Cured hams from pigs slaughtered in the cold season had extractible lipid percentage that were

0.2 percentage units greater than cured hams from pigs slaughtered in the hot season (P = 0.05) which resulted in poorer muscle bind indicated by a 0.41 kg reduction in bind strength of ham slices from pigs slaughtered in the cold season compared with bind strength values from pigs slaughtered in the hot season (P < 0.01; Table 4).

**Table 4.** Effect of seasonality on cured ham quality

| | Season | | | |
|---|---|---|---|---|
| | Cold | Hot | SEM | P-values |
| Green weight, kg | 5.17 | 5.02 | 0.17 | <0.01 |
| Pumped weight, kg | 6.20 | 6.04 | 0.21 | <0.01 |
| Pump percent, % | 19.77 | 20.44 | 0.61 | 0.02 |
| 30 minute drained weight, kg | 6.04 | 5.89 | 0.20 | <0.01 |
| Pump uptake, % | 16.64 | 17.30 | 0.46 | <0.01 |
| Stuffed weight, kg | 5.86 | 5.65 | 0.18 | <.0001 |
| Stuffed yield, % | 113.35 | 112.76 | 0.30 | 0.03 |
| Casing on cooked weight, kg | 11.52 | 11.07 | 0.34 | <0.0001 |
| Casing off cooked weight, kg | 11.40 | 10.92 | 0.34 | <0.0001 |
| Cooked yield, % | 99.95 | 98.66 | 0.33 | <0.0001 |
| Cured color | | | | |
| L* | 66.71 | 65.34 | 0.64 | <0.0001 |
| a* | 12.58 | 11.79 | 0.13 | <0.0001 |
| b* | 5.53 | 5.54 | 0.04 | 0.74 |
| Bind strength, kg | 7.56 | 7.97 | 0.12 | <0.01 |
| Proximate Composition | | | | |
| Moisture, % | 72.77 | 72.77 | 0.38 | 0.94 |
| Lipid, % | 5.11 | 4.91 | 0.73 | 0.05 |

Primal belly weights (P = 0.08) and flop distances (P = 0.94) were not different between pigs slaughtered in the cold season and pigs slaughtered in the hot season (Table 5). Even so, there were dimensional differences between the two sets of bellies. Bellies from pigs slaughtered in the cold season were 0.6 cm shorter, 1.1 cm wider, and 0.06 cm thicker (P < 0.0001) than bellies from pigs slaughtered in the hot season.

**Table 5.** Effect of seasonality on fresh belly quality

| | Season | | | |
|---|---|---|---|---|
| | Cold | Hot | SEM | P-values |
| Belly weight, kg | 7.47 | 7.40 | 0.26 | 0.08 |
| Flop score | 2.05 | 2.05 | 0.31 | 0.94 |
| Length, cm | 68.94 | 69.54 | 1.57 | <0.0001 |
| Width, cm | 36.39 | 35.29 | 0.55 | <0.0001 |
| Average Depth, cm | 2.56 | 2.50 | 0.12 | <0.0001 |

**Objective 3 - Characterize variation in carcass characteristics of pigs selected either for high lean growth potential or for more desirable meat quality.**

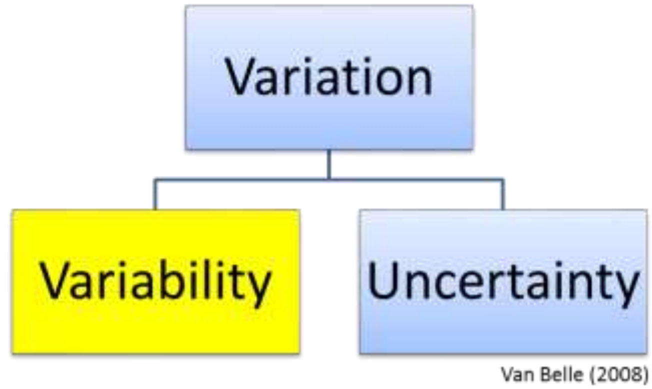


**Figure 1.** Components of total variation

Variation within a trait can be divided into variability and uncertainty (Fig 1). Uncertainty refers to the degree of precision in a measurement. Given that most measurements of carcass yield and meat quality are taken at the packer and processor, or even by the consumer, the pork producer can do little to reduce this portion of variation. For example, two people eating the same pork chop may rate it differently in terms of tenderness contributing variation to the measurement of this trait that is out of the control of the producer. On the other hand, variability is inherent variation that exists in a trait due to nature. It cannot be eliminated. At no point will the production of pork overcome the inherent variability of pigs. Pigs are living things and biology is variable. Therefore, variability will always exist. However, through management practices, we can strive to reduce variability. Current animal husbandry practices like raising pigs in a controlled environment, marketing pigs at a common weight, or feeding pigs a consistent diet are all tools used to reduce variability. Variance is a measure of variability (defined as the average of the squared differences from the mean) and portions of this variance of a particular trait can be assigned to various factors in a statistical model. To produce *consistently* high quality pork, it is crucial to understand which factors contribute large amounts of variance to a trait. These are the factors that producers can attempt to control during production and expect to have the most pronounced effect on overall variation.

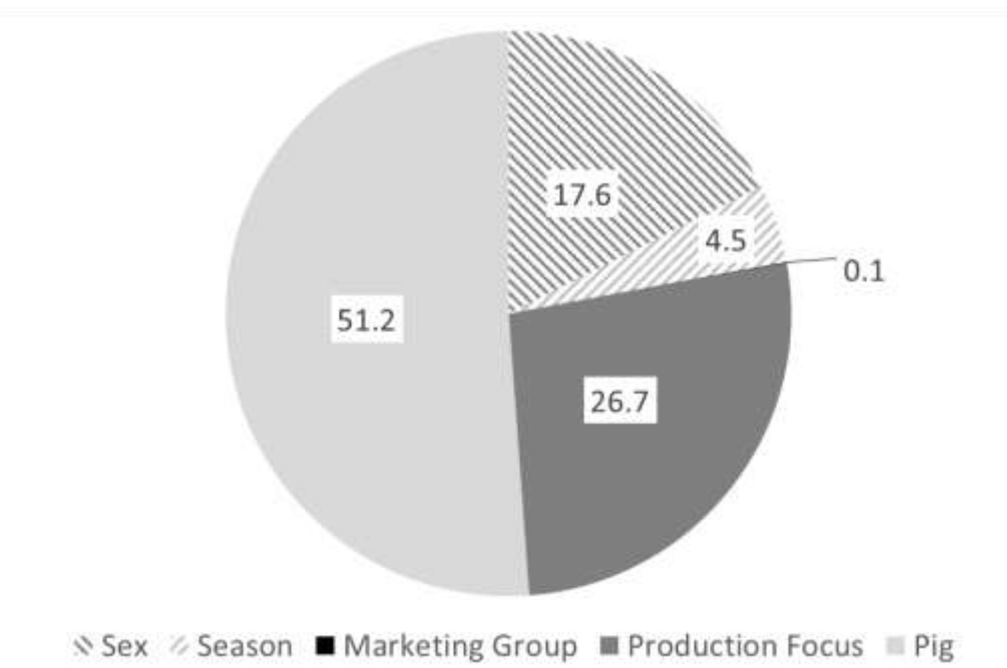


**Figure 2**. Percentage of total variation in 10th rib fat thickness (dependent variable) accounted for by the following independent variables: sex, season, marketing group, production focus, and pig.

Pigs are marketed in multiple groups within a barn to minimize variance in live weight. It is also expected that by controlling variance in ending live weight that variation in HCW, fat thickness, loin depth, and estimated carcass lean will also be controlled. Even though variation of some traits can be managed by marketing pigs in multiple groups, variation still exists. For producers to further reduce variation in these carcass traits, an understanding of what variables are contributing to total variance must be known. Total variance ($\sigma^2$) in 10$^{th}$ rib fat thickness was 15.92, 72.59 in loin depth, 7.62 in estimated carcass lean, and 428.49 in HCW. In each of the 4 dependent traits (fat thickness, loin depth, estimated carcass lean, and HCW) inherent variation from the pigs contributed the greatest percentage to total variance. Even so, other independent variables such as sex of the pig, season of slaughter, marketing group, and production focus (lean growth or meat quality) all contributed, though differently, to the variation of the different carcass traits. Production focus contributed 26.7% of total variance and sex contributed 17.6% of total variance in fat thickness. Some management practices, such as added dietary fat, are modified during hot seasons. Thus, seasonality contributed 4.5% of total variance in fat thickness. As said previously, pigs are marketed in multiple marketing groups to minimize variation in carcass traits, so it is not surprising that marketing group only contributed 0.1% of total variance in fat thickness (Fig 2). Production focus contributed 20.0%, seasonality contributed 16.1, marketing group contributed 2.0% and sex of the pigs contributed 1.4% of total variance in loin depth (Fig 3).

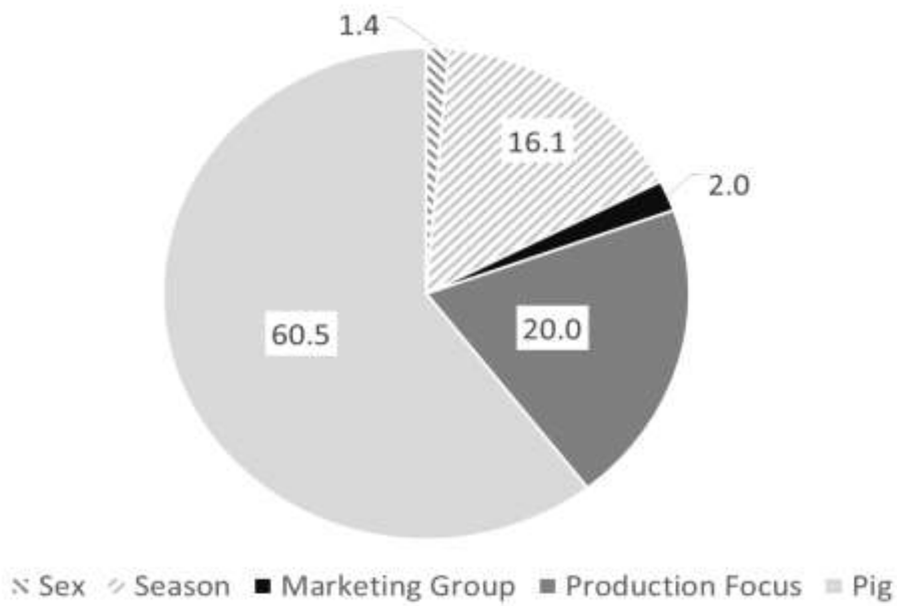


**Figure 3** Percentage of total variation in 10th rib loin depth (dependent variable) accounted for by the following independent variables: sex, season, marketing group, production focus, and pig.

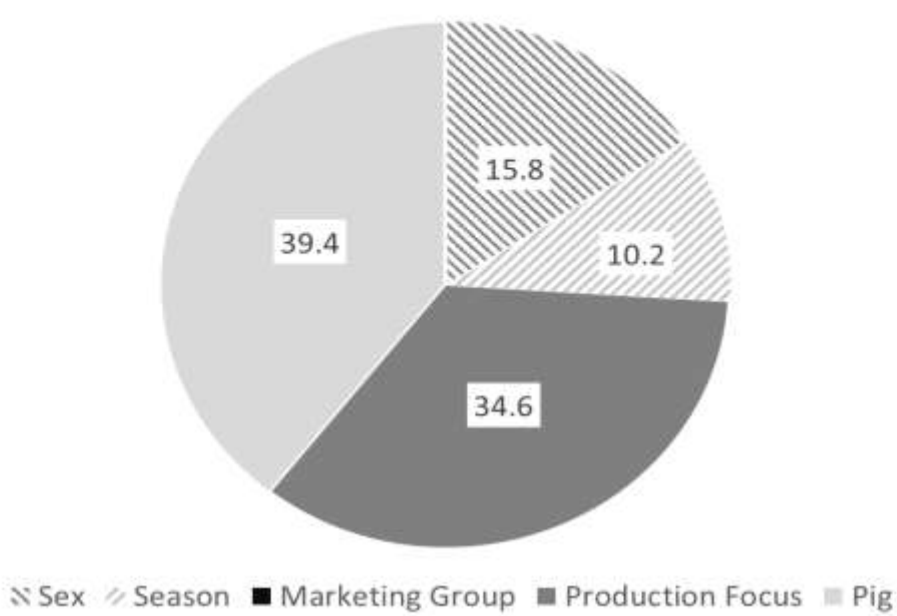


**Figure 4** Percentage of total variation in estimated carcass lean (dependent variable) accounted for by the following independent variables: sex, season, marketing group, production focus, and pig.

Production focus contributed 34.6%, seasonality contributed 10.2%, and sex of the pig contributed 15.8% to total variance in estimated carcass lean. Marketing group did not contribute to the total variance in estimated carcass lean. Again, this was not a complete surprise as pigs are marketed to manage variation in body weight and estimated carcass lean (Fig 4). Unlike with fat thickness, loin depth, and estimated carcass lean, inherent variation in the pig contributed to nearly all of the total variance for HCW. Pig contributed 93.5% of total variance in HCW. Production focus contributed 0.3%, marketing group contributed 4.1%, season contributed 0.8% and sex of the pig contributed 1.4% to the total variance in HCW. Although there was variation ($\sigma^2$ = 428.49) in HCW in these populations of pigs, the marketing strategies used reduced the contribution to total variance due to production focus, marketing group, seasonality, and sex to 6.6% of total variation (Fig 5).

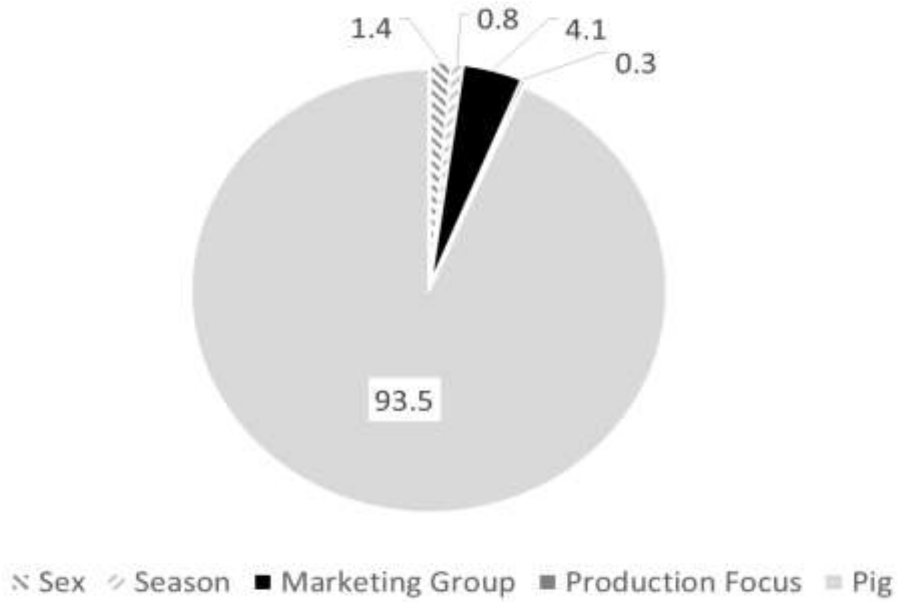


**Figure 5**. Percentage of total variation in hot carcass weight (dependent variable) accounted for by the following independent variables: sex, season, marketing group, production focus, and inherent variation of the pig.

**Discussion:**

From these results, the following conclusions can be drawn.

1) Meat quality of the entire carcass is not synonymous with loin quality. Carcasses with high quality loins do not necessarily produce high quality bellies and hams. The give and take in quality among the primal components requires more intensive investigation. *Factors that predict or measure processed ham and belly quality are largely undefined but are likely to be different from those defining fresh loin quality.* Relationships among primal quality parameters are limited to carcasses that were chilled in a rapid (blast) chill system. *A need still exists to characterize relationships among primal quality parameters in spray chill systems.*

2) Season of production does influence quality of pork carcasses. However, only limited conclusions about the direction and magnitude of those differences can be drawn from this study as only one instance of each season is present in the data. *Adding another replicate to this data set would provide additional statistical confidence to the data set and strengthen overall conclusions.*

3) While segregating pigs by marketing group or production focus may help to minimize uncertainty associated with total variance, variability in carcass traits still exists. Even so, the uncertainty component of variation was reduced in some carcass traits. Inherent variability due to the pig was the greatest contributor to total variance for HCW, loin depth, fat depth,

and estimated carcass lean. *Evaluation of contributors to total variance for loin, belly, and ham quality will provide an opportunity to further evaluate variation in meat quality characteristics.*