Title: Characterizing the relationship between early postmortem loin quality attributes with 14 day aged loin quality attributes and sensory characteristics – NPB #16-220

Investigator: Dustin Boler

Institution: University of Illinois

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Industry Summary:

The adoption of a pork quality grading system has the potential to change the way pork is valued by pork producers by assigning value to pork loins based on quality traits. Currently, producers are compensated for their pigs based on carcass weights and estimated carcass lean values. This means pork producers are paid based on a yield grade and little emphasis is placed on quality. In order to establish scenarios by which producers can be rewarded for producing high quality pork, a better understanding is needed of the relationships between quality evaluations made by the packer/processor and quality as evaluated by the consumer at both the point-of- purchase and when consuming pork products.

Loins (N =296) used in this project were from pigs from two different production focuses similar to those used in NPB #14-221. Carcasses were blast-chilled and then held in an equilibration cooler until approximately 22 h postmortem, when they were fabricated into primal cuts and boneless loins were further cut into boneless strap-on (longissimus costarum) center cut pork loins. Loins were randomly assigned within a production focus to target equal color and marbling scores for loins designated for aging as intact loins (n = 144) until 12 d postmortem or sliced into chops (n = 152) at 2 d postmortem and aged until 14 d postmortem as case-ready chops. Selected loins were removed from the de-boning line and subsequently evaluated for CIE instrumental lightness (L*), redness (a*), and yellowness (b*) (CIE, 1978), pH, visual color, marbling, and subjective firmness and weight. During initial evaluation at 1 d postmortem loins were randomly assigned to either project 1 (objective 1) or project 2 (objective 2 and 3). Half of the loins were aged as intact loins and stored in a dark cooler (4° C) until 12 d postmortem. At 12 d postmortem, loins were removed from their packaging and allowed a minimum of 30 minutes for oxygenation of myoglobin prior to ventral loin quality evaluation. Ventral loin evaluations at 12 d postmortem were performed by the same trained technician as conducted the same quality evaluations on 1 d postmortem. The other half of the loins were aged as case-ready chops and were removed from their vacuum sealed packaging at 2 d postmortem. Loins were then sliced into 28 mm chops. Chops were subsequently packaged in vacuum packages or placed in Styrofoam trays and overwrapped with PVC film. Overwrapped packages were placed in a gas-flushed modified atmosphere bulk package with sets of chops from a single loin placed in each bulk package. Chops were stored until 9 d

postmortem. At the conclusion of the aging period, chops were placed in a simulated retail display for 3d postmortem. Then, chops were cooked to either 63° C or 71° C and evaluated for sensory tenderness, juiciness, and flavor as well as instrumental slice shear force.

No differences were expected for ventral loin quality of loins designated for aging as intact loins or loins designated as case-ready chops because they were randomly assigned to aging treatments from a single set of loins within the two respective production focuses. There were no differences in early postmortem ventral quality except for redness values of intact loins were redder (P = 0.03) than case-ready loins. Aging treatment caused the chop surface of case-ready chops to be lighter (P < 0.001) and less red (P < 0.0001) than chop face of chops from intact loins after the aging period. Chops from case-ready loins also had greater (P < 0.0001) WBSF values and cook losses (P < 0.0001) than chops from intact loins. The ventral surface of intact loins became lighter (P < 0.0001), redder (P < 0.0001), and more yellow (P < 0.0001) during the postmortem aging period. Visual color and marbling did not change during the postmortem aging period, but pH declined (P < 0.0001).

Early postmortem color values on the ventral surface of the loin was correlated with aged postmortem color of the chop surface and those correlations did not differ regardless if a loin was aged as an intact loin or as a case-ready chop. Early postmortem ventral loin quality traits were not strongly correlated with WBSF or cook loss. Those correlations did not differ between intact loins and loins aged as case-ready chops.

There were no differences in sensory traits (P ≥ 0.30), slice shear force (P = 0.13), or cook loss (P = 0.06) among proposed USDA quality grades. There were no differences in sensory traits (P ≥ 0.06), slice shear force (P = 0.99), or cook loss (P = 0.12) between packaging types. Chops cooked to 63° C were rated more tender (P < 0.0001), more juicy (P < 0.0001) but less flavorful (P = 0.01) than chops cooked to 71° C. Likewise, chops cooked to 63° C had lesser slice shear force values (P = 0.01) and cook loss percentages (P < 0.0001) than chops cooked to 71° C.

Contact: Dustin Boler
University of Illinois
dboler2@illinois.edu
(217) 300-4847

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Scientific Abstract:

After fabrication and initial estimates of quality at 1d postmortem, boneless pork loins can be aged as intact loins or sliced for "case-ready" packages of loin chops. The objective was to determine the effect of aging method on loin chop quality and determine differences between aging methods for correlations among early and aged loin quality traits. Quality of boneless loins (N = 296) was evaluated at 1d on the ventral side. Loins were then allocated to either aging as intact loins (n = 144) or as case-ready chops (n = 152). Loins aged intact were vacuum packaged at 1d postmortem, aged at 4°C, and sliced into 28 mm thick chops at 12d postmortem. For case-ready packages, loins were sliced into 28mm chops at 2d postmortem, packaged in individual polyvinyl-chloride film overwrapped trays sealed in modified atmosphere packaging (MAP) bags at 4°C until 9d postmortem and then were displayed in a mock retail case. At 12d postmortem, instrumental color values were collected on one chop from each loin. Chops were then individually vacuum-sealed and aged to 14d postmortem, when Warner-Bratzler shear force (**WBSF**) and cooking loss were determined. Quality traits were compared between aging methods using a one-way ANOVA in the MIXED procedure of SAS. At 1d postmortem, quality traits were similar between aging methods (P ≥ 0.13), except loins designated for case-ready packages were

0.29 units (a*) less red ($P = 0.03$) than those to be aged intact. After aging, however, chops from case-ready packages were 0.52 kg less tender (WBSF), had 9% greater cook loss, and had 6.79 greater L* and 0.85 a* values (lighter and less red) than intact-aged chops ($P < 0.0001$). Correlations among early and aged loin quality traits within aging method were calculated in SAS using CORR procedure and compared between aging methods using a *z*-test for independent and dependent correlations. Early ventral lightness (L*) and redness (a*) from intact-aged loins ($r = 0.52$ L*; $r = 0.63$ a*) and case-ready chops ($r = 0.45$ L*; $r = 0.61$ a*) were correlated with aged chop lightness and redness values, respectively. These correlation coefficients did not differ between aging methods ($P \geq 0.43$). Correlation coefficients between WBSF and extractable lipid, early ventral loin color and L* did not differ ($P \geq 0.17$) between aging methods. Among early loin quality traits, only extractable lipid was correlated ($P \leq 0.05$) with WBSF. Therefore, while lightness, WBSF, and cooking loss differed between intact-aged and case-ready chops, correlations between early ventral and aged chop quality traits did not differ between aging methods. There were no differences in sensory traits ($P \geq 0.30$), slice shear force ($P = 0.13$), or cook loss ($P = 0.06$) among proposed USDA quality grades. There were no differences in sensory traits ($P \geq 0.06$), slice shear force ($P = 0.99$), or cook loss ($P = 0.12$) between packaging types. Chops cooked to 63° C were rated more tender ($P < 0.0001$), more juicy ($P < 0.0001$) but less flavorful ($P = 0.01$) than chops cooked to 71° C. Likewise, chops cooked to 63° C had lesser slice shear force values ($P = 0.01$) and cook loss percentages ($P < 0.0001$) than chops cooked to 71° C. Based on these data, cooking chops to 63° C rather than 71° C was a more effective way to improve eating experience than the newly proposed USDA quality grades. Further packaging type did not have any effect on eating experience of boneless loin chops aged for 14d postmortem.

Introduction:

The adoption of a pork quality grading system has the potential to change the way pork is valued by pork producers by assigning value to pork loins based on quality traits. Currently, producers are compensated for their pigs based on carcass weights and estimated carcass lean values. This means pork producers are paid based on a yield grade and little emphasis is placed quality. In order to establish scenarios by which producers can be rewarded for producing high quality pork, a better understanding is needed of the relationships between quality evaluations made by the packer/processor and quality as evaluated by the consumer at both the point-of- purchase and when consuming pork products.

When quality is evaluated by pork processors, evaluations are conducted on the ventral surface of a whole boneless loin that is fabricated 1 d after slaughter. However, when boneless pork chops are evaluated by consumers at retail, that evaluation occurs 10 to 17 days later. Consumers base these evaluations of quality on the cut surface of loin chops rather than on the ventral side of a whole loin. Both the processor and consumer evaluations, though, depend on visual appraisal of loins. However, when consumers bring home those products and prepare them, quality is judged not only visually but as an overall eating experience including sensory traits like tenderness, juiciness and flavor. Due to differences in both timing and in the product and characteristics being evaluated, this means that loins could be classified as high quality at the processing facility but may not necessarily be considered high quality at retail or provide a high quality eating experience. Therefore, a *critical need* exists to establish the relationship between early postmortem pork quality traits evaluated on the ventral surface of a whole loin with aged pork quality traits evaluated on the cut surface of a boneless pork chop and with sensory qualities of cooked pork chops. A pork quality grading system based on the visual appraisal of loins at the processor without strong evidence from consumer-level evaluations to support it would be compromised.

Overall, the *long term goal* of our research was to establish the relationship between early postmortem pork quality traits with aged pork quality traits to facilitate the improvement of pork quality overall and support systems that could reward producers for raising high quality pork. Our *primary objective* was to correlate fresh loin quality parameters (muscle pH, color, marbling, firmness) of loins at carcass fabrication (aged 1 day postmortem) with loin quality parameters (muscle pH, color, marbling, firmness, water-holding capacity, tenderness, and sensory characteristics) of those same loins available to consumers (aged for approximately 14 days postmortem). Our *central hypothesis* was that early postmortem pork quality traits are indicative of aged pork quality traits and sensory traits, but those relationships may differ depending on packaging of the chops and degree-of-doneness to which the chops are cooked. Our *rationale* for this research was that by gaining an appreciation of the relationship between early postmortem and aged loin quality, producers will have the tools necessary to critically evaluate the potential for implementation of a quality grading system.

Objectives:

Objective 1: Correlate fresh center cut boneless loin quality parameters (muscle pH, color, marbling firmness) of the ventral edge of loins aged 1 day postmortem with loin chop face and ventral edge quality parameters (muscle pH, color, marbling firmness, tenderness) of those same loins aged for 12 days postmortem.

Objective 2: Compare the relationship of fresh loin quality parameters of center cut boneless loins aged 1 day postmortem with loin chop quality parameters of chops from the same original loins aged for 14 days postmortem and packaged for aging in either vacuum or overwrap packages.

Objective 3: Compare the predictive ability of fresh loin quality parameters of center cut boneless loins aged 1 day postmortem for sensory characteristics of chops aged for 14 days postmortem when those chops are cooked to either a medium degree of doneness (71° C) or a medium rare degree of doneness (63° C).

Materials & Methods:

Pigs used for this study were from two separate production focus programs (lean growth and meat quality) similar to those used in NPB #14-221. Pigs were immobilized using carbon dioxide and terminated via exsanguination. Carcasses were blast-chilled and then held in an equilibration cooler until approximately 22 h postmortem, when they were fabricated into primal cuts and boneless loins were further cut into boneless strap-on center cut pork loins. Loins were imaged using a VQG pork loin grading camera on the ventral side of the loin immediately after fabrication. The VQG camera was used to select loins with variation in color and intramuscular fat content. A target of 36 loins were selected from each production focus for a total of 72 loins during each of 4 loin collection days. A targeted total of 288 loins were selected. There was an issue with sealing of loins during packaging of 8 loins during one of the blocks. Therefore, an additional 8 loins were selected during a subsequent evaluation period to provide a full set of loins. Loins were randomly assigned within a production focus to target equal color and marbling scores for loins designated for aging as intact loins (n = 144) until 12 d postmortem or sliced into chops (n = 152) at 2 d postmortem and aged until 12 d postmortem as case-ready chops. Selected loins were removed from the de-boning line and subsequently evaluated for CIE instrumental lightness (L*), redness (a*), and yellowness (b*) (CIE, 1978), pH, visual color, marbling, and subjective firmness and weight. Ventral evaluations were measured near the area of the 10^{th} rib. Instrumental lightness (L*), redness (a*), and yellowness (b*) scores were measured using a Konica Minolta CR-400 colorimeter (D65 light source, 10˚ observer, 8 mm aperture; Minolta Camera Company, Osaka, Japan) that was calibrated with a white tile prior to evaluations. Loin pH was measured using a MPI pH meter (Meat Probes Inc. pH-Meter, Topeka, KS) with a glass electrode probe that was calibrated prior to evaluations using pH 4 and pH 7 calibration buffers stored at 4°C. A trained technician evaluated visual color and marbling, using National Pork Producers Council (NPPC,

1999) color and marbling standards and subjective firmness using National Pork Producers Council (NPPC, 1991) scale. Visual color was assigned using a 6-point scale (1 = pale, grayish-pink; 6 = dark, purplish-red); visual marbling was assigned using a 10 point scale (1 = 1% intramuscular fat; 10 = 10% intramuscular fat), and subjective firmness was assigned using a 5 point scale (1 = soft; 5 = firm); all evaluations were determined in half score increments. Boneless loins were vacuum-packaged and transported in coolers with ice packs approximately 520 km to the University of Illinois Meat Science Laboratory for aging and further evaluations.

During initial evaluation at 1 d postmortem loins were randomly assigned to either project 1 (objective 1) or project 2 (objective 2 and 3). For project 1, Loins were aged as intact loins and stored in a dark cooler (4° C) until 12 d postmortem. At 12 d postmortem, loins were removed from their packaging and allowed a minimum of 30 minutes for oxygenation of myoglobin prior to ventral loin quality evaluation. Ventral loin evaluations at 12 d postmortem were performed by the same trained technician as conducted the same quality evaluations on 1 d postmortem and followed the same procedures and used the same equipment as previously described. Aged evaluations consisted of CIE instrumental lightness (L*), redness (a*), and yellowness (b*), pH, subjective color, marbling, and firmness and weight. Loins were sliced into 28 mm thick chops. Chops were selected starting from the anterior end of the loin with the first selected chop containing a posterior portion of the spinalis dorsi (Fig. 1). Chops were assigned to meat quality evaluations in the following order: 1) Warner-Bratzler shear force (**WBSF**), 2) extractable lipid content, 3-10) randomized for cut chop surface quality evaluations. Chop 1 was vacuum-packaged and stored at 4°C until 14 d postmortem for evaluation of instrumental tenderness. Chop 2 was trimmed of subcutaneous fat, connective tissue, and accessory muscles, vacuum-packaged, and stored at -20°C until evaluation of extractable lipid content. Chops were allowed at least 30 minutes for oxygenation of myoglobin before surface evaluations were conducted. Evaluations for instrumental CIE lightness, redness, and yellowness and visual color, marbling, and subjective firmness, used the same equipment and procedures described for 1 d postmortem evaluations.

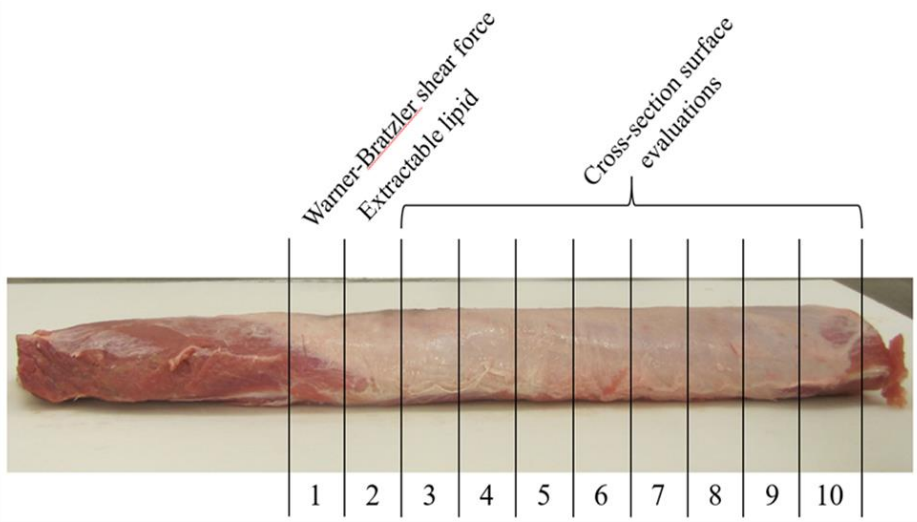

Figure 1. Loins were sliced into 28mm thick chops. Chops were randomly assigned to instrumental and sensory evalautions. Chop 1 was designated for Warner-Bratzler shear force. It was the most anterior chop used and contained the posterior portion of the spinalis dorsi. Chop 2 was used to determine extractable lipid content. Chops 3-10 were either packaged in individual vacuum-sealed packages or in PVC overwrapped trays packaged in gas-flushed bulk packages. A chop from each loin desgnated for each packaging type was cooked to either 63° C or 71° C. Chops from each of the 4 packaing types and degree of doneness combiantions were evaluted for slice shear force or sensory tenderness, juiciness, and flavor.

Loins aged as case-ready chops were removed from their vacuum sealed packaging at 2 d postmortem. Loins were sliced into 28 mm chops using a PUMA slicer (TREIF USA Inc., Shelton, CT). Chops were selected and assigned to packaging type (vacuum sealed or case-ready PVC overwrap) or degree of doneness in the same manner as intact loins. Chops were allowed at least 30 minutes for oxygenation of myoglobin before surface evaluations occurred. Evaluations were instrumental CIE lightness, redness, and yellowness and visual color, marbling, and subjective firmness using the same equipment and procedures described at 1 d postmortem. Chops were packaged in a 13.65cm^2 tray (polystyrene Cascades Evok) on top of an absorbent pad (Ultra ZAP Soaker) and overwrapped in polyvinyl chloride (PVC) film (O_2 transmission = 23,250 mL·m^2·d^{-1}, 72 gauge; Resinite Packaging Films, Borden, Inc., North Andover, MA). Each chop was standardized by trimming subcutaneous fat and accessory muscles and then weighed. Packages of chops originating from the same loin were placed in a 35.56 cm x 50.80 cm vacuum sealable bag gas-flushed bag with 600 millibars of a gas mixture (0.2% - 0.4% carbon monoxide, 23% - 30% carbon dioxide, and 60% - 80% nitrogen). The bulk packages were boxed and aged in a cooler at 4°C until 9 d postmortem. At 9 d postmortem, chops were removed from boxes and bulk packaging, and placed in simulated retail display under fluorescent lighting (General Electric 32W, 122cm fluorescent Kitchen/Bath bulb in an Utilitech 121 cm 2-light fixture suspended 30.5 cm above the chops) in the overwrapped trays. This was done to simulate the potential scenario of chops being displayed on a grocery store retail case, resulting in an increased exposure to light. At 12 d postmortem (3 d after simulated retail display), chops were evaluated for instrumental CIE lightness, redness, and yellowness with the same equipment and procedures described at 1 d postmortem. Case-ready chops and vacuum packaged chops were frozen at 14d postmortem after the case-ready chops were evaluated for shelf-life characteristics.

Sensory panel sessions consisted of six individuals who evaluated pork chop tenderness, juiciness, and pork flavor. Panelists were selected from a pool of trained students and faculty from the University of Illinois (Champaign-Urbana, IL). Panelist training focused on determining standards of tenderness, juiciness, and pork flavor. Sensory panelists were standardized to pork tenderness by cooking one chop to an internal temperature of 60 °C and a second chop to 80 °C. Panelists were standardized to juiciness by cooking a non-enhanced chop and an enhanced chop both to an internal temperature of 68 °C. Panelists were standardized to flavor by cooking a pork chop and 80:20 % lean:fat ground pork to an internal temperature of 71° C. Panelists would evaluate samples individually in a breadbox-style booth with red overhead lights to mask color differences. Chops were assigned to sensory sessions using an incomplete randomized block schedule of chops for each sensory panel and this was generated using the OPTEX procedure in SAS

Vacuum packaged chops were removed from -20 °C and place in a 4 °C cooler 24 h prior to cooking to allow for proper thawing. Chops were removed from their individual vacuum bags and weighed prior to cooking. Chops were cooked to either medium-rare degree of doneness (63° C internal temperature) or medium degree of doneness (71° C internal temperature). Chops were cooked on a Farberware Open Hearth grill (model 455N, Walter Kidde, Bronx, NY, USA) with a copper-constantan thermocouple (Type T, Omega Engineering, Stamford, CT, USA) inserted into the geometric center of each chop to accurately monitor internal cooking temperature on a digital thermometer (model 92000-00, Barnat Co, Barrington, IL, USA). Chops were initially cooked to an initial internal temperature of either 31 °C (medium-rare) or 36 °C (medium) and then flipped. Once chops were cooked to their assigned final internal temperature, they were immediately removed, weighed, and placed on an aluminum tray for cooling. After chops cooled for a 3-min rest period, subcutaneous fat and connective tissue was removed from each chop to ensure accurate evaluation of only lean tissue. Chops were then cut using a 1 cm x 1 cm sample sizer. Panelists were given two random cubes per sample. Each testing day consisted of 2 sessions, at most, with 8 samples per session. Each session evaluated chops from 2 loins with all four combinations of packaging type and degree of doneness combinations represented. Sessions were held at least 1 h apart to reduce sensory fatigue. The study consisted of 576 samples in 72 sessions over 36 d. Results from all 6 panelists were averaged for use in data analyses. Based on the proposed quality grades, there was only 1 loin that received a “USDA Prime grade” in the set of loins used for case-ready chop evaluations. Therefore, only 572 chops were included in the analysis.

Statistical Analyses

Loin and chop quality parameters measured at 1 d, 12 d, and 14 d postmortem from loins aged as intact loins and loins aged as case-ready chops were compared using a one-way ANOVA in the MIXED procedure of SAS 9.4 (SAS Inst. In., Cary, NC). The model included the fixed effect of aging treatment and the random effect of slaughter date. Each individual loin served as the experimental unit for all dependent variables. Least squared means and standard errors were reported for all measured attributes and significance levels were considered different at $P \leq 0.05$ for all analyses.

Comparisons were made between 1 d postmortem and 12 d postmortem ventral surface loin quality (intact aged loins only, n = 144) with a paired T-test in the PROC TTEST procedure of SAS. Significance levels were considered different at $P \leq 0.05$.

A z-test was used to compare two independent correlations. Comparison of independent correlations among early and aged quality traits between loins aged as intact loins or case-ready chops were achieved using the CORR procedure to calculate and transform correlation coefficients with the FISHER option in SAS. The Fisher's r to z transformation equation was defined as:

Eq. 1.

$$z = \frac{1}{2} \ln \left[\frac{1+r}{1-r}\right]$$

The Pearson correlation coefficient is represented as r and z is the value of the transformed correlation coefficient. Fisher's transformed z values were then merged into a single data set for comparison of independent correlation coefficients. Data were compared based on the following equation:

Eq. 2.

$$z = \frac{z_{roasts} - z_{chops}}{\sqrt{\dfrac{1}{n_{roasts} - 3} + \dfrac{1}{n_{chops} - 3}}}$$

The correlations between 1 d postmortem ventral loin traits with 14 d WBSF and cooking loss (r_{13}) was compared with the correlations between 12 d postmortem loin traits with 14 d WBSF and cooking loss (r_{23}). Because the correlations being calculated were not derived from different, independent populations and the correlations being compared shared a common trait (14 d WBSF or cooking loss), they were considered dependent. That is, r_{12} is correlated with r_{13}, therefore the influence of the relationship of between 1 d postmortem and 12 d postmortem ventral loin quality traits (r_{12}) must be accounted for when comparing r_{13} with r_{23}. To achieve this, three sets of Pearson correlation coefficients were calculated (r_{13}, r_{23}, and r_{12}) and the correlation coefficients were transformed using Fishers r to z equation (Eq. 1). Then, the test statistic, t was calculated using the following equation:

Eq. 3.

$$t = \frac{(r_{23} - 0.05 r_{12} r_{13})(1 - {r_{12}}^2 - {r_{13}}^2 - {r_{23}}^2) + {r_{23}}^3}{(1 - {r_{12}}^2)(1 - {r_{13}}^2)}$$

The resulting test statistic (t) was then compared with t_{critical} from a t distribution. Correlations were considered different if the z value was statistically significant. Correlations were considered weak at $|r| < 0.35$, moderate at $0.36 \geq |r| < 0.67$, and strong at $|r| \geq 0.68$. Analysis in data sets exceeding 100 observations may result in correlation coefficients of 0.20 that have little practical importance despite being statistically different from 0 ($\alpha = 0.05$). Therefore, comparisons between correlations of early and aged postmortem loin quality by aging treatment were considered significantly different at $P \leq 0.05$ with a corresponding correlation coefficient of $|r| \geq 0.36$ to ensure practical significance.

Sensory and slice shear force data were analyzed with the MIXED procedure of SAS as split-split plot design. Individual loin served as the experimental unit and the fixed effects in the model were production focus of the pigs, proposed USDA quality grade, packaging type, and degree of doneness and all possible interactions. Sensory session served as the blocking factor and was coded as a random variable. The whole plot factor of production focus and quality grade was tested with the three-way interaction of session, focus, and quality grade. The split plot was packaging type (vacuum packaging or PVC overwrap) and was tested with the four-way interaction of session, quality grade, focus, and packaging type. The split-split plot was degree of doneness (63° C or 71° C) and was tested with the five-way interaction of session, quality grade, focus, packaging type, and degree of doneness. There were no interactions among production focus and the other treatments of interest. Therefore, production focus interactive data were pooled among the other parameters not presented.

Results:

Objective 1

No differences were expected for ventral loin quality of loins designated for aging as intact loins or as case-ready chops. There were no differences in early postmortem ventral quality except for redness values of loins aged as roast were redder ($P = 0.03$) than loins aged as chops. Aging treatment caused loins aged as chops to be lighter ($P < 0.001$) and less red ($P < 0.0001$) than loins aged as roasts after the aging period. Loins aged as chops also had greater ($P < 0.0001$) WBSF values and cook losses ($P < 0.0001$) than loins aged as roasts.

Table 1. Effects of aging loins either as roasts or as chops on quality parameters measured early postmortem (1 d) on the ventral surface of whole boneless loins and aged quality parameters measured on the cross-section surface of chops

Item	Aged Intact Loins	Aged Case-ready Chops	SEM	*P*-value
Loins, n	144	152		
1 d Postmortem Ventral				
Lightness[1], L*	43.34	43.90	0.51	0.13
Redness[2], a*	7.90	7.61	0.19	0.03
Yellowness[3], b*	0.62	0.62	0.13	0.99
NPPC color[4]	3.34	3.41	0.21	0.34
NPPC marbling[5]	2.16	2.08	0.08	0.28
NPPC firmness[6]	2.81	2.80	0.26	0.82
Ultimate pH[7]	5.73	5.73	0.05	0.92
Chops, n	144	144		
12 d Postmortem Chop face				
Lightness[1], L*	49.99	56.78	0.84	< 0.0001
Redness[2], a*	8.18	7.33	0.17	< 0.0001
Yellowness[3], b*	2.66	2.56	0.16	0.41
Extractable lipid, %	2.39	2.30	0.16	0.43
14 d Postmortem Chop face				
Warner-Bratzler Shear force, kg	2.62	3.14	0.07	< 0.0001
Cook loss, %	19.72	21.59	0.94	< 0.0001

[1]L* measures darkness to lightness (greater L* indicates a lighter color)
[2]a* measures redness (greater a* indicates a redder color)
[3]b* measures yellowness (greater b* indicates a more yellow color)
[4]NPPC color based on the 1999 standards measured in half point increments with 1 = palest; 6 = darkest.
[5]NPPC marbling based on the 1999 standards measured in half point increments where 1 = least amount of marbling; 6 = greatest amount of marbling.
[6]NPPC firmness based on the 1991 scale measured in half point increments with 1 = softest; 5 = firmest.
[7]Ultimate pH collected on the ventral surface of the whole boneless loin.

The ventral surface of loins aged as roasts became lighter ($P < 0.0001$), redder ($P < 0.0001$), and more yellow ($P < 0.0001$) during the postmortem aging period. Visual color and marbling did not change during the postmortem aging period, but pH declined ($P < 0.0001$).

Table 2. Comparison of ventral loin quality traits of early (1 d) postmortem quality and aged (12 d) postmortem quality from aged intact loins[1]

	Days postmortem				
Item	1 d	12 d	Difference	SED[2]	*P*-value
Loins, n	144	144			
Lightness[3], L*	43.34	46.62	-3.29	0.23	< 0.0001
Redness[4], a*	7.90	9.02	-1.12	0.09	< 0.0001
Yellowness[5], b*	0.62	2.95	-2.33	0.09	< 0.0001
NPPC color[6]	3.34	3.35	-0.01	0.05	0.84
NPPC marbling[7]	2.16	2.18	-0.02	0.04	0.64
NPPC firmness[8]	2.81	2.37	0.44	0.08	< 0.0001
Ventral loin pH[9]	5.73	5.66	0.07	0.01	< 0.0001

[1]Early and aged postmortem quality data were compared using a paired-T test on the same loin

[2]Standard error of the difference of the mean

[3]L* measures darkness to lightness (greater L* indicates a lighter color)

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

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

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

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

[8]NPPC firmness based on the 1991 scale measured in half point increments with 1 = softest; 5 = firmest.

[9] Ultimate pH collected on the ventral surface of the whole boneless loin

Early postmortem ventral instrumental color values were correlated (r ≥ 0.35) with aged postmortem chop face instrumental color values. The correlations between early loin surface and aged chop surface did not differ (*P* ≥ 0.43) between loins aged as roasts and loins aged as chops from instrumental lightness and redness. The correlation between early ventral yellowness and aged chop yellowness was stronger (*P* = 0.04) among loins aged as roasts compared with loins aged as chops.

Table 3. Comparison of independent Fisher's r to z transformed correlation coefficients (rho) of early (1 d) postmortem ventral loin quality and aged (12 d) postmortem cross section chop quality

Early ventral postmortem loin variable	Aged postmortem chop variable	Aged Intact Loins			Aged Case-Ready Chops			
			95% Confidence limit[1]			95% Confidence limit[1]		
		Rho	Lower	Upper	Rho	Lower	Upper	*P*-[4] value[5]
Lightness[2], L*	Lightness[2], L*	0.52	0.39	0.63	0.45	0.31	0.57	0.43
Redness[3], a*	Redness[3], a*	0.63	0.11	0.41	0.61	0.11	0.41	0.76
Yellowness[4], b*	Yellowness[4], b*	0.54	0.42	0.65	0.35	0.20	0.49	0.04

[1]Confidence intervals not including zero (0) are considered different from 0.

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

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

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

[5]Probability value comparing correlation coefficients, using r to z transformed values, of quality traits between loins aged 12 d as either roasts or chops

Instrumental Warner-Bratzler shear force and cook loss was correlated with some early postmortem ventral traits. However, none of those correlations were greater than 0.33 and therefore likely do not represent a practical relationship. Even so, the correlations among early postmortem ventral loin quality and WBSF and cook loss mostly did not differ between loins aged as roasts and loins aged as chops.

Table 4. Comparison of independent Fisher's r to z transformed correlation coefficients (rho) of early postmortem loin quality traits between loins aged as roasts or chops for Warner-Bratzler shear force (WBSF) and cook loss

Early postmortem ventral loin variable	Aged Intact Loins			Aged Case-Ready Chops			
		95% Confidence limit[1]			95% Confidence limit[1]		
	Rho	Lower	Upper	Rho	Lower	Upper	*P*-value[2]
WBSF							
Extractable lipid	-0.23	-0.38	-0.07	-0.17	-0.32	-0.01	0.61
NPPC color	0.17	0.00	0.32	0.14	-0.02	0.29	0.81
NPPC marbling	-0.08	-0.24	0.08	-0.10	-0.26	0.06	0.87
NPPC firmness	0.15	-0.01	0.31	-0.10	-0.26	0.06	0.03
Lightness, L*	-0.14	-0.30	0.02	-0.30	-0.44	-0.15	0.17
Redness, a*	-0.11	-0.27	0.05	-0.08	-0.24	0.08	0.79
Yellowness, b*	-0.01	-0.17	0.16	-0.17	-0.32	-0.01	0.16
Cook loss, %							
Extractable lipid	0.18	0.02	0.34	0.00	-0.15	0.16	0.12
NPPC color	-0.12	-0.28	0.05	0.18	0.02	0.33	0.01
NPPC marbling	0.08	-0.08	0.24	0.11	-0.05	0.26	0.85
NPPC firmness	-0.01	-0.17	0.15	0.11	-0.05	0.27	0.28
Lightness, L*	0.11	-0.05	0.27	-0.06	-0.22	0.10	0.15
Redness, a*	0.01	-0.15	0.18	0.11	-0.05	0.26	0.41
Yellowness, b*	0.05	-0.12	0.21	0.12	-0.04	0.28	0.52

[1]Confidence intervals not including zero (0) are considered different from 0.

[2]Probablity value comparing correlation coefficients of meat quality traits between loins aged as roasts or chops

Table 5. Comparison of independent Fisher's r to *z* transformation correlation coefficients (rho) comparisons of aged postmortem chop quality traits between loins aged as roasts or chops for Warner-Bratzler shear force (WBSF) and cook loss

Aged postmortem chop variable	Aged Intact Loins			Aged Case-Ready Chops			
		95% Confidence limit[1]			95% Confidence limit[1]		
	Rho	Lower	Upper	Rho	Lower	Upper	*P*-value[2]
WBSF							
Extractable lipid	-0.23	-0.38	-0.07	-0.17	-0.32	-0.01	0.61
Lightness, L*	-0.17	-0.32	0.00	-0.07	-0.23	0.10	0.39
Redness, a*	0.00	-0.17	0.16	-0.15	-0.31	0.01	0.21
Yellowness, b*	-0.14	-0.30	0.02	-0.03	-0.19	0.14	0.33
Cook loss, %							
Extractable lipid	0.18	0.02	0.34	0.00	-0.15	0.16	0.12
Lightness, L*	0.03	-0.14	0.19	-0.09	-0.25	0.07	0.32
Redness, a*	0.04	-0.13	0.20	0.01	-0.15	0.18	0.83
Yellowness, b*	0.05	-0.12	0.21	0.38	0.23	0.51	< 0.001

[1] Confidence intervals not including zero (0) are considered different from 0.

[2]Probablity value comparing correlation coefficients of meat quality traits between loins aged as roasts or chops

Table 6. Comparison of dependent Fisher's r to z transformed correlation coefficients (rho) from aged intact loins at early (1 day) postmortem and aged (12 day) postmortem for Warner-Bratzler shear force (WBSF) and cook loss

Ventral variable	1d postmortem			12d postmortem			
		95% Confidence limit[1]			95% Confidence limit[1]		
	Rho	Lower	Upper	Rho	Lower	Upper	*P*-value[2]
WBSF							
NPPC color	0.17	0.00	0.32	0.17	0.00	0.32	0.98
NPPC marbling	-0.08	-0.24	0.08	-0.15	-0.3	0.02	0.58
NPPC firmness	0.15	-0.01	0.31	-0.01	-0.18	0.15	0.15
Lightness, L*	-0.14	-0.30	0.02	-0.17	-0.32	0.00	0.83
Redness, a*	-0.11	-0.27	0.05	0.00	-0.17	0.16	0.14
Yellowness, b*	-0.01	-0.17	0.16	-0.14	-0.30	0.02	0.18
Cook loss, %							
NPPC color	-0.12	-0.28	0.05	-0.08	-0.24	0.08	0.78
NPPC marbling	0.08	-0.08	0.24	0.06	-0.10	0.22	0.86
NPPC firmness	-0.01	-0.17	0.15	-0.08	-0.25	0.08	0.52
Lightness, L*	0.11	-0.05	0.27	0.03	-0.14	0.19	0.34
Redness, a*	0.01	-0.15	0.18	0.04	-0.13	0.20	0.81
Yellowness, b*	0.05	-0.12	0.21	0.05	-0.12	0.21	0.99

[1]Confidence intervals not including zero (0) are significant correlations ($P \leq 0.05$).

[2]Probablity value comparing correlation coefficients of meat quality traits between loins aged as roasts or chops

Objective 2 and 3

Table 1. Lean quality estimates of boneless pork loins from pigs either selected for lean growth or meat quality traits or categorized based on USDA grade standards of pork carcasses.

	Production focus			USDA quality grade[1]				*P* - values		
Item	Lean	Quality	SEM	Standard	Select	Choice	SEM	Focus	USDA quality grade	Focus x quality grade
Loins, n	78	73		43	13	95				
Loin wt, kg	5.40	5.03	1.07	5.40[b]	5.19[ab]	5.07[a]	1.08	< 0.01	0.01	0.44
Ventral pH	5.69	5.72	0.05	5.72[ab]	5.65[a]	5.75[b]	0.06	0.20	0.02	0.95
Lightness[2], L*	43.80	45.23	0.51	44.20[b]	46.14[c]	43.21[a]	0.80	0.01	< 0.01	0.41
Redness[2], a*	7.36	7.83	0.20	7.16[a]	7.83[b]	7.79[b]	0.32	0.05	0.01	0.62
Yellowness[2], b*	0.46	0.87	0.20	0.41	0.95	0.64	0.29	0.04	0.15	0.15
Color[3]	3.08	3.16	0.15	3.27[b]	2.49[a]	3.60[c]	0.20	0.55	< 0.0001	0.69
Extractable lipid, %	2.12	2.51	0.23	1.61[a]	2.77[b]	2.56[b]	0.30	0.04	< 0.0001	0.78
Marbling[3]	1.95	2.03	0.07	1.28[a]	2.27[b]	2.42[b]	0.11	0.39	< 0.0001	0.73
Firmness[3]	2.62	2.76	0.28	2.46[a]	2.66[ab]	2.95[b]	0.32	0.34	< 0.01	0.63

[1]USDA quality grades are based on the newly proposed grade standards for pork carcasses where: Choice = NPPC color score of 3 and a NPPC marbling score ≥ 2, Select = NPPC color score of 2 and a NPPC marbling score ≥ 2, Standard either has a NPPC color score < 2 or a NPPC marbling score < 2.

[2]L* = measure of lightness (greater value indicates a lighter color), a* = measure of redness (greater value indicates a redder color), and b* = measure of yellowness (greater value indicates a more yellow color).

[3]NPPC color (1 = pale pink to 6 = dark purplish red), NPPC marbling (1 = 1% intramuscular lipid to 10 = ≥10% intramuscular lipid), and NPPC firmness (1 = very soft to 5 = very firm) were based on NPPC (1991, 1999) standards.

Differences in loin quality traits between lean and quality focused loins were similar to those observed in NPB #14-221. Loins from quality focused pigs had greater ($P = 0.04$) extractable lipid percentage than loins from lean focused pigs but visual marbling scores did not differ ($P = 0.39$). Loins categorized as USDA select were lighter ($P < 0.05$) than loins categorized as USDA choice or loins that did not meet the requirements for choice or select (standard). As outlined in the guidelines for pork loin quality evaluation neither marbling nor extractable lipid differed ($P > 0.05$) between USDA choice or USDA select. Both USDA choice and USDA select had greater marbling and greater extractable lipid scores than Standard loins. There were no interactions ($P \geq 0.15$) between production focus and USDA quality grade for lean quality traits, therefore, production focus was pooled for all subsequent analyses.

Table 2. Effects of USDA quality grade on trained sensory and instrumental tenderness values of boneless pork loin chops

	USDA quality grade[1]				
Item	Standard	Select	Choice	SEM	*P*-value
Chops, n	152	52	368		
Tenderness[2]	8.97	9.09	9.24	0.25	0.30
Juiciness[2]	8.52	8.40	8.61	0.19	0.49
Flavor[2]	2.08	2.10	2.07	0.05	0.89
Slice shear force[3], kg	11.05	10.12	10.90	0.43	0.13
Cook loss, %	12.36	12.05	11.92	0.27	0.06

[1]USDA quality grades are based on the newly proposed grade standards for pork carcasses where: Choice = NPPC color score of 3 and a NPPC marbling score ≥ 2, Select = NPPC color score of 2 and a NPPC marbling score ≥ 2, Standard either has a NPPC color score < 2 or a NPPC marbling score < 2.

[2]Evaluated on a 15 point scale, where 0 = extremely tough, dry, or not flavorful and 15 = extremely tender, juicy, or flavorful.

[3]Slice shear force; cooked to a final internal temperature of 63° C or 71° C and sheared at internal temperature of approximately 22° C.

Table 3. Effects of packaging type on trained sensory and instrumental tenderness values of boneless pork loin chops

	Packaging type			
Item	Vacuum	PVC[2]	SEM	*P*-value
Chops, n	286	286		
Tenderness[1]	9.02	9.18	0.11	0.06
Juiciness[1]	8.47	8.55	0.10	0.32
Flavor[1]	2.08	2.09	0.03	0.74
Slice shear force[3], kg	10.69	10.69	0.32	0.99
Cook loss, %	12.49	11.74	0.18	0.12

[1]Evaluated on a 15 point scale, where 0 = extremely tough, dry, or not flavorful and 15 = extremely tender, juicy, or flavorful.

[2]PVC = polyvinyl chloride film. Chops were place in a polystyrene tray and wrapped in PVC film. Chops were placed in a gas flushed bag and flushed to 600 millibars of a gas mixture (0.2-0.4% carbon monoxide, 23-30% carbon dioxide, and 60-80% nitrogen).

[3]Slice shear force; cooked to a final internal temperature of 63° C or 71° C and sheared at internal temperature of approximately 22° C.

Table 4. Effects of internal degree of doneness on trained sensory and instrumental tenderness values of boneless pork loin chops

	Degree of doneness			
Item	63° C	71° C	SEM	*P*-value
Chops, n	286	286		
Tenderness[1]	9.31	8.89	0.11	< 0.0001
Juiciness[1]	8.94	8.08	0.10	< 0.0001
Flavor[1]	2.05	2.11	0.03	0.01
Slice shear force, kg	10.30	11.08	0.32	0.01
Cook loss, %	11.29	12.93	0.18	< 0.0001

[1]Evaluated on a 15 point scale, where 0 = extremely tough, dry, or not flavorful and 15 = extremely tender, juicy, or flavorful.

There were no differences in sensory traits ($P \geq 0.30$), slice shear force ($P = 0.13$), or cook loss (0.06) among proposed USDA quality grades. There were no differences in sensory traits ($P \geq 0.06$), slice shear force ($P = 0.99$), or cook loss ($P = 0.12$) between packaging types. Chops cooked to 63° C were rated more tender ($P < 0.0001$), more juicy ($P < 0.0001$) but less flavorful ($P = 0.01$) than chops cooked to 71° C. Likewise, chops cooked to 63° C had lesser slice shear force values ($P = 0.01$) and cook loss percentages ($P < 0.0001$) than chops cooked to 71° C.

Table 5. Interactive least square means of proposed USDA quality grade and packaging type on sensory traits of boneless pork loin chops

	USDA quality grade x Packaging type							*P*- value
	Standard		Select		Choice			
Item	Vacuum	PVC[2]	Vacuum	PVC[2]	Vacuum	PVC[2]	SEM	Quality grade x Packaging type
Chops, n	76	76	26	26	184	184		
Tenderness[3]	8.81[a]	9.14[b]	9.23[b]	8.96[ab]	9.03[ab]	9.46[b]	0.27	0.01
Juiciness[3]	8.42	8.61	8.47	8.32	8.52	8.70	0.21	0.24
Flavor[3]	2.08	2.07	2.06	2.13	2.09	2.05	0.06	0.17
Slice shear force, kg	10.85	11.25	10.37	9.88	10.86	10.93	0.53	0.38
Cook loss, %	12.76	11.97	12.42	11.68	12.28	11.56	0.33	0.93

[1]USDA quality grades are based on the newly proposed grade standards for pork carcasses where:

Choice = NPPC color score of 3 and a NPPC marbling score ≥ 2, Select = NPPC color score of 2 and a NPPC marbling score ≥ 2, Standard either has a NPPC color score < 2 or a NPPC marbling score < 2.

[2]PVC = polyvinyl chloride film. Chops were place in a polystyrene tray and wrapped in PVC film. Overwrapped Packages were placed in a gas flushed bag and flushed to 600 millibars of a gas mixture (0.2-0.4% carbon monoxide, 23-30% carbon dioxide, and 60-80% nitrogen).

[3]Evaluated on a 15 point scale, where 0 = extremely tough, dry, or not flavorful and 15 = extremely tender, juicy, or flavorful.

Table 6. Interactive least square means of proposed USDA quality grade and degree of doneness on sensory traits of boneless pork loin chops

	USDA quality grade x Degree of doneness							*P*- value
	Standard		Select		Choice			
Item	63° C	71° C	63° C	71° C	63° C	71° C	SEM	Quality grade x Degree of doneness
Chops, n	76	76	26	26	184	184		
Tenderness	9.22	8.73	9.30	8.89	9.43	9.06	0.27	0.67
Juiciness	8.95	8.09	8.81	7.99	9.05	8.17	0.21	0.94
Flavor	2.07	2.09	2.05	2.15	2.04	2.10	0.06	0.41
Slice shear force, kg	10.55	11.55	9.89	10.36	10.46	11.34	0.51	0.53
Cook loss, %	11.42	13.31	11.33	12.77	11.14	12.70	0.31	0.06

[1]USDA quality grades are based on the newly proposed grade standards for pork carcasses where: Choice = NPPC color score of 3 and a NPPC marbling score ≥ 2, Select = NPPC color score of 2 and a NPPC marbling score ≥ 2, Standard either has a NPPC color score < 2 or a NPPC marbling score < 2.

Table 7. Interactive least square means of packaging type and degree of doneness on sensory traits of boneless pork loin chops

	Packaging type x Degree of doneness					
	Vacuum		PVC[1]			*P*- value
Item	63° C	71° C	63° C	71° C	SEM	Packaging type x Degree of doneness
Chops, n	143	143	143	143		
Tenderness[2]	9.23	8.81	9.39	8.97	0.13	0.97
Juiciness[2]	8.87	8.08	9.01	8.09	0.11	0.38
Flavor[2]	2.06	2.10	2.05	2.13	0.04	0.35
Slice shear force, kg	10.76	10.63	9.84	11.54	0.46	0.32
Cook loss, %	11.48	13.49	11.10	12.37	0.26	0.81

[2]PVC = polyvinyl chloride film. Chops were place in a polystyrene tray and wrapped in PVC film. Overwrapped packages were placed in a gas flushed bag and flushed to 600 millibars of a gas mixture (0.2-0.4% carbon monoxide, 23-30% carbon dioxide, and 60-80% nitrogen).
[2]Evaluated on a 15 point scale, where 0 = extremely tough, dry, or not flavorful and 15 = extremely tender, juicy, or flavorful.

II. Discussion:

From these results, the following conclusions can be drawn.

1) Early postmortem color values on the ventral surface of the loin is correlated with aged postmortem color of the chops surface and those correlations do not differ regardless if a loin is aged as an intact loin or as a case-ready chop. Early postmortem ventral loin quality traits were not strongly correlated with WBSF or cook loss. Those correlations did not differ between intact loins and case-ready chops.

2.) Early postmortem color is related to aged color and early postmortem marbling is related to aged marbling but neither are correlated with eating experience.

3) There were no differences in sensory traits ($P \geq 0.30$), slice shear force ($P = 0.13$), or cook loss (0.06) among proposed USDA quality grades. There were no differences in sensory traits ($P \geq 0.06$), slice shear force ($P = 0.99$), or cook loss ($P = 0.12$) between packaging types. Chops cooked to 63° C were rated more tender ($P < 0.0001$), more juicy ($P < 0.0001$) but less flavorful ($P = 0.01$) than chops cooked to 71° C. Likewise, chops cooked to 63° C had lesser slice shear force values ($P = 0.01$) and cook loss percentages ($P < 0.0001$) than chops cooked to 71° C.

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