RESEARCH REPORT

ANIMAL SCIENCE

Title: Effects of Pork Quality and Cooked Temperature on Consumer and Trained Sensory Perception of Eating Quality in Non-enhanced and Enhanced Pork Loins – **NPB #06-139 and #07-005**

Investigator: Steve Moeller

Institution: The Ohio State University

Co- Investigators: Rhonda Miller, Henry Zerby - Texas A&M University

Date Submitted: July 1, 2008

For more information contact:

National Pork Board, P.O. Box 9114, Des Moines, Iowa USA

800-456-7675, **Fax:** 515-223-2646, **E-Mail:** porkboard@porkboard.org, **Web:** http://www.porkboard.org/

Industry Summary

Project Design and Objectives

The present study was conducted to evaluate the influences of fresh pork color (Minolta L*), intramuscular fat (IMF), and ultimate pH (pH), and cooked pork Warner Bratzler shear force (WBS) on consumer and trained sensory perception of pork loin (chop) eating quality. Trained and sensory assessments of eating quality were assessed at four end-point cooked temperatures (62.8° C (145° F); 68.3° C (155° F); 73.9° C (165° F); and 79.4° C (175° F). The effects of variation in quality and cooked temperature were assessed for both non-enhanced and enhanced (10% pump rate, 2.5% potassium lactate, 0.35% sodium phosphate, and 0.35% salt) pork loin chops. Loins used in testing were collected from three cooperating U.S. packing plants, with selection designed to capture the variation in and combinations of Minolta L*, IMF, and pH observed in the U.S pork industry in an attempt to understand the individual influence each quality attribute as well as potential interactions among quality attributes as they relate to eating quality of pork. Consumer testing was conducted in Chicago, Philadelphia and Sacramento, targeting 760 consumers within each test market. Trained sensory testing was conducted at Texas A&M University and Iowa State University.

Non-enhanced Loin Findings

Consumer responses were assessed on an 8-point scale with a rating of 1 representing a very unfavorable response and a rating of 8 representing a very favorable response. For non-enhanced pork over all attributes assessed, predicted mean consumer responses were consistently near or slightly under five on the 1 to 8 point end-anchored scale, indicating a very neutral or slightly unfavorable perception of pork eating quality regardless of variation in fresh quality measures or cooked temperature. Increasing cooked temperature of the non-enhanced chops reduced ratings for consumer perceptions of juiciness, tenderness and overall-like, with the effect being most pronounced when comparing the lowest cooked temperature (145° F) with the greatest cooked temperature (175° F). Intramuscular fat level had a significant, but small impact on consumer perception of eating quality attributes; increasing juiciness, tenderness, and overall-like ratings, but only of a measurable and practical influence when comparing the least (1% IMF) with the greatest (6% IMF) levels. Consumer response ratings were greatly influenced by loin pH and WBS. Increasing loin pH from a base of 5.40 to 6.40 resulted in ~1.0 unit favorable improvements in mean responses for tenderness and juiciness ratings. As WBS increased, consumer ratings for tenderness, juiciness, and overall-like decreased, with the most favorable ratings (≥ 5 on the 8-point scale) occurring for WBS levels of < 2.5 kg shear force, a value representing the mean WBS of chops cooked to 145 F. Increasing WBS to 4.0 kg resulted in mean consumer ratings near 4.0 on the 8-point scale. Minolta L* had no statistical influence on consumer perception of eating quality in the present study when assessed with the effects of pH, IMF, WBS and cooked temperature in the model.

Trained sensory responses were evaluated using a 10-point end anchored intensity scale. Panelists assessed tenderness, chewiness, juiciness, fat flavor, lean flavor, and saltiness attributes. The negative influence of increasing cooked temperature on juiciness ratings was in a similar direction, but of a greater magnitude in the trained panel when compared with the consumer ratings. Increasing cooked temperature by 10° F reduced trained panel ratings by 0.38 units, resulting in an overall 11.5% reduction in juiciness ratings when comparing 145° F and 175° F end-point cooked temperatures. Trained panelists ratings for pork tenderness were near 6.5, on the 10-point scale, a mean value indicative of a moderate level of tenderness for the non-enhanced pork. Increasing cooked temperature from 145° F to 175° F reduced mean ratings by a small, but significant 0.27 units in the present study. Cooked temperature had no statistical influence on either fat flavor or lean flavor as assessed by the trained panel. At the average WBS (~2.65 kg) the mean trained panel rating for tenderness was ~ 6.70 units on the 10-point scale. Increasing WBS in 0.50 kg increments reduced mean tenderness ratings by ~3.8%, resulting in mean ratings near 4.69 for chops with WBS of 5.0 kg and near 3.91 for chops with WBS of 6.0 kg, the toughest chops tested in the study. Incrementally increasing WBS by 0.50 kg led to reductions in trained panel juiciness (- 1.8%) and lean flavor (- 2.5%) ratings, an indication that tougher chops were perceived as less juicy and having less lean flavor. Loin pH influenced trained panel perceptions of tenderness, juiciness, and fat flavor in a curvilinear manner with chops from loins with a pH level of 5.60 or less receiving much lower (unfavorable) ratings when compared with chops from loin with a pH of 5.8 or greater. The curvilinear influence of pH on trained panel attributes suggests that loins with lower pH (≤ 5.60) were clearly less desirable and that, while the magnitude of the influence of loin pH on sensory attributes decreases at a slower rate beyond a pH of 5.80, trained panelists continued to rate chops more favorably up to a pH of 6.40 for nearly all attributes. Trained panels reported significant, but very small improvements in tenderness, chewiness, juiciness, and flavor ratings as IMF increased; however, similar to the observed influence of IMF on consumer responses, the effects observed were of practical value only when comparing the ends of the 1% to 6% range. Minolta L* color contributed to a significant, but very small effect on trained panel ratings for juiciness, tenderness, and lean flavor, with the palest chops (Minolta L* = 65.0, Color score 1) receiving measurably lower ratings when compared with the darkest (Minolta L* 46.9, Color score 5) chops evaluated and very limited differentiation in ratings when comparing and contrasting adjacent color scores (ie Color Score 1 vs. 2 or 3 vs. 4).

Based on the consumer and trained sensory response data collected, shear force and loin pH were the two primary pork quality attributes that influenced perceptions of pork eating quality for non-enhanced chops. However, both measures present logistical and technical challenges for use as either classification or sorting tools within the industry. For example, loin pH has been shown to be greatly influenced by the environment beginning with the pig at the farm and continuing through the chilling process within the packing plant. Coupled with challenges related to instrumentation and the inability to capture pH on every carcass at existing line speeds within U.S. packing plants, pH, while valuable, remains a challenging tool to implement. Shear force assessment, as measured in the present study, requires the pork to be cooked, resulting in a loss of product, difficulty in maintaining identity, and storage of remaining product until results are known and used as a sorting or marketing tool. Therefore, while results of the present study provide evidence for the value of shear force and pH as indicators of quality, implementation strategies that improve the logistical challenges present or development of new technologies to meet the challenges are necessary for the industry to make a concerted effort toward improvement of pork eating quality.

Results of the present study suggest that a reduction in the recommended cooked temperature from the existing 160° F to a lesser degree of doneness (either 145° F or 155° F) would have a positive influence on juiciness, tenderness and likelihood of purchase of non-enhanced chops, particularly for consumers that currently cook pork chops or loins to temperatures that exceed 160° F. Lowering the cooked temperature would have little influence on pork flavor attributes which were rated relatively low in both consumer and trained sensory panels. Loin intramuscular fat improved eating quality as measured by the trained and consumers panels when comparing the upper end of the observed range (6% IMF) with the lower extreme (1% IMF) which is likely to have the greatest industry value when utilized as a trait in targeted- or niche-market scenarios where consumers are willing and able to pay for the extra cost that is often associated with producing pigs that have greater loin IMF. The influence of loin color, although significant only in the trained panel, on eating quality was very small or not present in the current study and is an indication that the contributions of pH and or shear force may have overridden or accounted for the individual contribution of color to eating quality variation. Color will likely remain a valuable indicator of eating quality in the fresh state because visual appeal plays a large role in point of purchase decisions, particularly for very pale or PSE-like pork.

Non-enhanced Loin Findings

Enhancement has been a tool used by the pork packing and processing industries to improve eating quality characteristics of pork. In the present study, a subset of loins were collected within a single packing facility and paired based on similarities in loin quality attributes. One loin from each paired loin set was enhanced and the other remained in the fresh state as a non-enhanced loin. The data were analyzed as a subset of the full consumer and trained sensory portions of the present study.

Increasing cooked temperature had little influence on WBS of enhanced chops, while WBS of non-enhanced chops increased and the difference between enhanced and non-enhanced chops increased as cooked temperature increased in the present study. The interactive influence on WBS for enhanced chops was observed in direct comparisons of consumer responses, whereby increasing cooked temperature of non-enhanced chops resulted in small but consistent reductions in consumer satisfaction, while for enhanced loins as cooked temperature increased consumer ratings were either not changed or were improved slightly. When comparing enhanced with non-enhanced chops at the cooked temperature extremes of 145° F and 175° F, the predicted mean ratings for enhanced chops increased by 0.73 and 1.15 units respectively for Juiciness Like, 0.81 and 1.08 units respectively for Tenderness Like, 1.1 and 1.31 units respectively for Flavor Like, and 0.88 and 1.13 units respectively for Overall Like. Enhancement improved consumer perceptions of eating quality even at a low cooked temperature, with the impact increasing as cooked temperature increased. Enhancement also improved trained sensory panel ratings for juiciness (5.4%), tenderness (6.8%), chewiness (2.6%), but had no influence on fat or lean flavor levels when assessed across the range of cooked temperatures assessed. In contrast with consumer responses, the enhancement effect was consistent at each cooked temperature.

Loin intramuscular fat had no influence on consumer ratings for tenderness like or level, and a significant, but very small (1.3% change over the range of 1% to 6% IMF) influence on trained sensory ratings for tenderness when assessed for both enhanced and non-enhanced chops. Increasing loin IMF improved consumer ratings for juiciness like and level by ~2.5% and trained sensory ratings for juiciness ~3.0%, favoring chops with 6% IMF over chops with 1% IMF for both enhanced and non-enhanced chops. At equal levels of IMF, enhanced chops were rated 11.3% more juicy by the consumer panelists and 5.6% more juicy by the trained panel.

Loin pH influenced consumer perceptions of eating quality in a non-linear fashion across the range of pH evaluated resulting in larger incremental changes in mean responses when increasing loin pH from 5.40 to 5.60 for all descriptive attributes when compared with changes in loin pH from 5.80 to 6.00, 6.00 to 6.20, and 6.20 to 6.40. Consumer perceptions of loin juiciness attributes were optimized at a loin pH in the range of 5.80 – 6.00 and optimized for loin tenderness in the range of 6.00 to 6.40 across both enhanced and non-enhanced chops. Loin pH had no measurable influence on trained sensory juiciness, chewiness, lean flavor, or saltiness ratings; however, increasing loin pH from a low of 5.40 to the upper level of 6.40 improved tenderness ratings by 6.4% and fat flavor ratings by ~3.6% for both enhanced and non-enhanced chops. Consumers rated flavor attributes most favorably at a loin pH of 5.80, while trained panelist responses for fat flavor increased as pH increased from 5.40 up to 6.00, and changed only slightly as pH increased up to 6.40.

Enhancement improved consumer ratings for juiciness and tenderness attributes by approximately 12% across the range of WBS evaluated in the study, a finding somewhat larger than the 5.5% improvement in juiciness ratings and the 7.00% improvement in tenderness ratings observed in the trained panel evaluation. In addition, the influence of WBS on trained and consumer ratings for juiciness and tenderness were large and consistent across both enhanced and non-enhanced chops. Trained sensory ratings for tenderness were reduced by 3.3% for each 0.50 kg increase in WBS while consumer ratings were reduced ~3.5% for each 0.50 kg increase in WBS for both enhanced and non-enhanced chops, indicating that tougher pork was identified as being less desirable in both enhanced and non-enhanced chops; however, the additive influence of enhancement allowed enhanced chops to have greater mean ratings for tenderness at greater levels of WBS.

Results from the present study reinforce the significant positive influence that enhancement has on consumer and trained sensory perceptions of pork eating quality across the wide range of fresh pork quality attributes observed in the U.S. swine industry. Enhancement offered protection against overcooking and allowed pork with low pH and high WBS values to be rated as good as or better than non-enhanced pork measured at the optimal levels of pH and WBS. Based on the results of the present study, enhancement appears to offer significant improvements in eating quality when compared with non-enhanced loins with similar fresh pork quality attributes.

Project Objectives

The present study utilized commercially derived loins specifically selected to capture the variation in and combinations of pork quality present in the U.S. pork industry as a base for assessment of eating quality. Using these loins as the basis for comparison, the objectives of the present study were:

1) Evaluate the potential independent and interactive influences of commonly measured pork quality indicators, including fresh loin color, pH, and intramuscular fat, and cooked pork tenderness on trained sensory and consumer panel perceptions of non-enhanced pork loin eating quality.

2) Evaluate the potential independent and interactive influences of commonly measured pork quality indicators, including loin color, pH, intramuscular fat, and tenderness on trained sensory and consumer perceptions of enhanced pork loin eating quality

3) Assess the impact of cooked temperature and potential interactions of cooked temperature with pork quality attributes on trained sensory and consumer perceptions of eating quality for both enhanced and non-enhanced pork loins.

Materials and Methods

Loin Selection Criteria

Loins were selected to represent and test combinations of fresh pork color (Objective Minolta L* and NPPC Visual Color), loin ultimate pH, and intramuscular fat (Marbling and Chemical IMF) that encompass the normal range of industry observed values for each quality attribute. For selection purposes, a 3 x 3 x 3 classification arrangement of pH, marbling score and Minolta L* color was used to create a near uniform representation of quality combinations for subsequent testing in trained and consumer taste panels. Initial loin classification criteria were: loin pH, < 5.5 (low), 5.5 to 5.8 (middle), and > 5.8 (high); loin L*, > 55 (pale), 49 to 55 (normal), and < 49 (dark); loin marbling scores of < 2.0 (low), 2.0 to 4.0 (middle), and > 4.0 (high). Due to the strong negative correlation between L* and pH, loins with greater pH values and greater L* values, as well as those with lesser pH and lesser L* were considered to be biologically impossible to obtain and those classification cells were not tested in the present study. Using the initial loin classification information, nearly 1800 loins (N = 455 enhanced loins, n = 1340 non-enhanced loins) were collected within three cooperating commercial U.S. pork packing facilities.

Prior to final loin selection, chemical intramuscular fat (IMF) percentage was used as a replacement for marbling score, and the loins were placed into categorical subclasses defined by 0.10 ph, 1% IMF, and 3.9 L* increments to form a final three dimensional matrix. Using the loin matrix distribution as a guide, loins were selected to create a nearly uniform distribution across quality attributes both within and across each packing plant of origin in an attempt to standardize testing of quality attributes for loins that were to be subsequently served in consumer and trained sensory taste panels. In total, 679 non-enhanced loins were selected in nearly equal proportions within three commercial U.S. pork packing facilities (n = 228, 228, and 223 loins, respectively), and 228 enhanced loins were selected from within a single packing plant.   Product utilized in the present study was collected during the fall of 2006 and spring 2007 with a total of 20 days of in-plant selection.

Loin Quality Assessment

Whole, boneless loins were collected along the fabrication line within each plant at approximately 24 h postmortem. Using the size of the spinalis dorsi muscle as an anatomical indicator, the loin was cut at approximately the 7th rib and the cut surface allowed to bloom for 10 min. Loin pH (HI98240, Hanna Instruments, Italy) was measured using a glass-tipped pH probe (FC201D, Hanna Instruments, Italy) inserted approximately 1 cm under the cut surface and placed in the center on the exposed 7th rib loin surface. After the bloom, loin color was measured on the exposed 7th rib loin surface by using a Minolta Colorimeter (CR-310, 50 mm diameter orifice, 10° standard observer, D^{65} light source; Minolta Company, Ramsey, New Jersey), recording L*, a* and b* values. Subjective visual color and marbling scores were collected by trained personnel using a 1 to 6 scale as outlined by the National Pork Producer Council (NPPC, 2000).

A 1.25 cm-thick section of loin was cut immediately posterior to the 7th rib exposed location, subcutaneous fat and connective tissue removed, and the remaining muscle sample used for assessment of IMF according to the ether extract using AOAC (1995) procedures. Chemical IMF procedures were carried out at Texas A&M University under the direction of Dr. Rhonda Miller. Moisture and fat amounts were attained by the air-dry oven and Soxhlet ether extraction methods, respectively. Approximately 2 g of powdered sample from each chop was added to dried, pre-weighed thimbles (filter paper #1, Whatman®, Maidstone, England) and weights were recorded. Analysis of the samples was performed in triplicate. The samples were dried in a convection oven at 100°C for 18-24 h then removed and placed in a dessicator for cooling. Weights were taken and recorded to determine percent moisture. Samples were placed in a Soxhlet apparatus and refluxed with petroleum ether for approximately 18 h. Samples were removed and placed under a hood to allow ether to evaporate, and placed in a convection oven for approximately 12 h. Samples were removed and placed in a dessicator until cooled to room temperature. Weights were taken and recorded to determine percent fat in each sample. Following collection of the IMF sample and loin quality measurements, the loins were weighed and individually vacuum sealed for storage and transportation. All loins were transported under refrigeration to The Ohio State University Meat Science Laboratory, Columbus, OH where the loins were stored and aged at 2° C for 7 to 10 days, with processing occurring on the Friday following the previous sampling week.

Enhancement Procedures

Within one of the cooperating packing facilities one-half of the loins selected were subjected to enhancement with salt, phosphate, and potassium lactate. Within this plant, loins were paired based on quality attributes and alternately assigned to either enhancement or non-enhancement treatments and then transported to the facility's research and development center where loin weights were recorded. Loins designated for the enhancement treatment were pumped via needle injection to target inclusion rates of: 10% pump rate, 2.5% potassium lactate, 0.35% sodium phosphate, and 0.35% salt. Enhanced loins were re-weighed following enhancement to calculate individual pump yield. Both enhanced and non-enhanced loins were vacuum sealed and transported to The Ohio State University Meat Science Laboratory, Columbus, OH where the loins were stored and aged at 2° C for 7 to 10 days.

Loin Processing

After aging, loins were removed from their package and weighed to assess loin purge loss. Loins were then tempered on racks in at -28.8 °C, creating a slightly frozen surface to allow for uniform slicing. Beginning at the anterior end, loins were sliced into twelve, 2.54 cm-thick chops. Chops were subsequently randomly assigned to three destinations (consumer sensory evaluation, trained sensory evaluation, or Warner-Bratzler Shear Force (WBS) assessment) and, within each destination, to four end point cooked temperatures (62.8° C (145° F); 68.3° C (155° F); 73.9° C (165° F); or 79.4° C (175° F). Random assignment of chops within a loin to a en-point designation and temperature end-point avoided confounding of chop location within the loin and the loin quality assessment data which was only collected at ~ 7^{th} rib location on each loin. Allocated chops were individually packaged using a roll-stock machine and frozen at -28.8° C until used within their respective designated destination.

Warner-Bratzler Shear Force

Warner-Bratzler shear force chops were weighed prior to and after thawing to assess thaw purge. Chops were cooked using a clam-style cooker (George Foreman grill) to the designated internal temperature. Internal temperatures (Digi-sense, Model # 277653 or equivalent) were monitored by copper constant thermocouplers (Digi-sense, K-type probe, 30.48 cm x 1.016 cm diameter, Code 93631-11 or equivalent) inserted into the geometric center of each chop. Chops were removed from the grill at their designated temperature with cooking time, temperature, and cooked weight recorded. Cook loss was measured using pre- and post-cooked weights. Chops were cooled for four hours to approximately 22.2° C prior to tenderness assessment. Six, 1.27 cm diameters cores were removed from each chop parallel to the longitudinal orientation of the muscle fibers. Each core was sheared with a Warner-Bratzler shearing device (Model TA.XT2^{plus} Texture Technologies, Scarsdale, New York) with a probe travel distance of 40 mm from the base, a pre-test speed of 5 mm/s, a test speed was 3.33 mm/s and a post-test speed of 20 mm/s.

Consumer Evaluation Procedures

Consumer taste panels were conducted in Chicago IL (October, 2006), Philadelphia, PA (April, 2007), and Sacramento, CA (May, 2007). Consumer recruitment was conducted via telephone interview through a consumer consulting agency under contract with the National Pork Board. Recruitment parameter targets, as specified by National Pork Board Demand Enhancement Staff personnel, included: 1) primary household grocery shoppers, 2) females aged 25 to 49, 3) annual household income of $30,000+, and 4) presence of children under 16 in the household. Male pork consumers were also included in this study with a target representation of 35% to 40% of the total respondents. Within each city, 760 consumers were secured and allocated to consumer panel sessions resulting in a total of 2280 consumers polled. Consumer taste panel sessions occurred over a two week period within each city, with 20 consumers in each testing session and 38 sessions per city.   Sessions were approximately 45 minutes in length, with 5 to 6 sessions conducted per testing day. ong.

Consumers were provided samples from eight different chops and five different consumers assessed samples from each chop. Chops were assigned to sessions using the following criteria: 1) each consumer was provided samples from two non-enhanced chops from each packing plant (three plants represented) to balance for plant of origin, 2) each consumer was provided samples from two chops that had been enhanced (one plant of origin), 3) chops were randomly assigned across end-point cooked temperature and fresh pork quality indicators within each plant for both enhanced and non-enhanced chops, and 4) serving order was randomized across the eight chops assigned to a group of five respondents. Consumer data analyses were conducted in two steps: 1) data representing non-enhanced chops were assessed independently, and 2) data comparing the enhanced chops with the non-enhanced chops collected within the same packing plant were analyzed independently.

Chops were cooked using a clam-style cooker (George Foreman grill) to the designated internal temperature as previously described for the assessment of shear force. Internal temperatures (Digi-sense, Model # 277653 or equivalent) were monitored by copper constant thermocouplers (Digi-sense, K-type probe, 30.48 cm x 1.016 cm diameter, Code 93631-11 or equivalent) inserted into the geometric center of each chop and removed from the cooker at the target internal temperature. Cooking yield, cook time, and final temperature were recorded. Immediately after cooking, chops were cut into 1.27 cm width × 1.27 cm length × 2.54 cm height cubes (0.5 in. width × 0.5 in. length × 1.0 in. height) with two cubes placed in serving boats and representing a sample for each consumer.

Samples were served under red incandescent lighting to minimize potential degree of doneness color appearance bias. Consumers were asked to cleanse their pallet prior to the first and between samples with an unsalted saltine cracker and distilled water. The consumer ballot consisted of seven preference related questions measured on an 8-point, end anchored Hedonic scale with the consumer marking the box of their choice. Following the ballot order, the questions were: Overall Like/Dislike, 1 = Dislike Extremely and 8 = Like Extremely; Like/Dislike Juiciness, 1 = Dislike Extremely and 8 = Like Extremely; Level of Juiciness, 1 = Extremely Dry and 8 = Extremely Juicy; Like/Dislike Tenderness, 1 = Dislike Extremely and 8 = Like Extremely; Level of Tenderness, 1 = Extremely Tough and 8 = Extremely Tender; Like/Dislike Flavor, 1 = Dislike Extremely and 8 = Like Extremely; Level of Flavor, 1 = Extremely Bland or No Flavor and 8 = Extremely Flavorful. For analyses ballot responses were labeled 1 through 8 in correspondence with the Hedonic scale. The final ballot question asked 'How likely would you be to purchase this sample if it were available at a reasonable price in your area?' Likelihood of Purchase response options were: Definitely Would Not Buy, Probably Would Not Buy, May or May Not Buy, Probably Would Buy, and Definitely Would Buy. For analyses, responses were labeled 1 through 5, with 1 representing Definitely Would Not Buy and 5 representing Definitely Would Buy.

Trained Sensory Panel Evaluation Procedures

Trained sensory panels were conducted at Texas A&M University or Iowa State University to accommodate the large number of samples (n = 3616) within the full research study. Testing required approximately 83 days within each sensory panel location. Loins were sorted within packing plant of origin based on the final three-dimensional loin quality classification criteria and were alternately assigned to either TAMU or ISU trained sensory panels in an attempt to establish a near uniform representation of quality variation within each panel location. Four chops within a loin, representing the four cooked temperatures, were tested within the same panel. Panel training sessions utilizing chops cut from non-test loins that varied in overall quality were conducted prior to initiation of the sensory portion of the study to standardize panels against the sensory assessment instrument.

Sensory panels consisted of five trained individuals evaluating ~ 24 samples per test day with a balanced representation of non-enhanced chops from each of the three packing plants and the enhanced chops derived from the single packing plant. Panelists were provided a ‘warm-up’ sample for panel calibration prior to each testing session. Chop cooked temperature was random within a given trained panel testing session. Chops were cooked using the George Foreman grill as described previously for both Consumer Panel and WBS assessments. Cooked yield, cook time, and final temperature were recorded only in the Texas A&M taste panel. Immediately after cooking, chops were cut into 1.27 cm width × 1.27 cm length × 2.54 cm height cubes (0.5 in. width × 0.5 in. length × 1.0 in. height) with two cubes placed in serving boats and representing a sample for each trained panelist.

Samples were served under red incandescent lighting to minimize sample color differences due to differing end-point temperatures. Panelists cleansed their pallet prior to the first and between samples with an unsalted, saltine cracker and distilled water. The trained sensory ballot consisted of five questions measured on a 10-point categorical intensity scale. The questions were: Juiciness, 1 = Dry and 10 = Juicy; Tenderness, 1 = Tough and 10 = Tender; Chewiness, 1 = Not Chewy and 10 = Very Chewy; Cooked Pork Fat Flavor, 1 = None and 10 = Intense; Saltiness, 1 = None and 10 = Intense. Within the Texas A&M panel, Cooked Pork Lean Flavor was evaluated whereby, 1 = None and 10 = Intense.

Statistical Analyses

Data from the present study were analyzed separately for Consumer and Trained Sensory panels. Within both panels, analyses were conducted to assess associations between quality measurements and panel responses for subsets of data that included: 1) only non-enhanced loins and 2) non-enhanced and enhanced loins derived from the same packing plant. The present study was designed for analyses using regression procedures. Consumer and Trained Sensory data were analyzed using ordered logistical regression through STATA software (StataCorp, LP, College Station, TX) and the output parameters summarized using CLARIFY V 2.1 (King, Tomz & Wittenberg, 2000). Associations between shear force and fresh pork quality attributes were conducted using standard regression procedures in STATA software ((StataCorp, LP, College Station, TX). Results are presented individually for each analysis performed, pairing trained sensory and consumer panel data sets for 1) non-enhanced loins only and 2) enhanced vs. non-enhanced analyses.

Consumer Panel- Non-enhanced Loin Study

Abstract

The study was designed to evaluate the interactive and individual effects of fresh pork loin (n = 679) ultimate ph (pH), intramuscular fat (IMF), Minolta L* color (L*), Warner-Bratzler shear force (WBS), and 4 cooked temperatures (62.8 °C, 68.3 °C, 73.9 °C, and 79.4 °C) on consumer perception of pork eating quality. Consumers (n = 2280) were provided samples representing eight chops (n = 13,265 observations). Data were analyzed using ordered logistical regression. Overall, predicted mean responses were consistently near or slightly under five on the 1 to 8 point end-anchored scale, indicating a very neutral to unfavorable perception of pork eating quality regardless of fresh quality or cooked temperature. Consumer mean responses improved as IMF and pH increased and WBS decreased, whereas L* did not contribute significantly to variation for any consumer response variable. While significant for all consumer response variables, increasing IMF resulted in a very small incremental improvement in responses and was of practical size only when comparing the least (1%) to the greatest (6%) levels of IMF. Loin pH and WBS were primary contributors to consumer perception, whereby incremental increases in pH (0.20 unit) and decreases in WBS (4.9 N) resulted in a 4 to 5% change in the predicted proportion of consumers rating pork as ≥ 6 (favorable) on the 8-point scale. No interactions between quality and or temperature effects were observed, indicating no thresholds or dependencies were observed for quality trait. Increased cooked temperature was significantly and negatively associated with a consumer's Overall-Like and Tenderness ratings; however, the magnitude of change was small and likely only of value when comparing least to greatest cooked temperatures. Increased cooked temperature had the greatest impact on Juiciness-Like and Juiciness-Level, whereby the mean consumer response changed by 0.50 unit across the range. Consumer responses favor pork with lower WBS, greater pH and IMF, and pork cooked to lower end-point temperatures.

Key Words: Pork Quality, Tenderness, Temperature, Consumer Preference, Ultimate pH

Consumer Non-enhanced Statistical Models

Dependent variables included consumer responses to ballot questions for non-enhanced loins only, representing product derived from three packing plants and only six of the eight chop samples consumed by panelists. Preliminary statistical models tested the continuous independent variables: cooked temperature, pH, IMF, L*, a*, b*, WBS, NPPC color, and NPPC marbling as linear and quadratic effects, and the two-way interactions among independent variables were tested. Plant of origin and city of testing were included as independent effects and, where significant, the effects were accounted for in reporting of the results. A linear covariate for the temperature deviation of observed cooked temperature from the designated treatment temperature was tested in all analyses and found not significant but was maintained in all final models to correctly assess temperature treatment effects. Plant of origin and both a* and b* color values were not significant effects in any models and were removed from final models. Model solutions were used to estimate predicted mean response levels and predicted consumer response proportions for, and encompassing the range of, each independent variable in the regression model. Correlation statistics were used to describe linear relationships among variables of interest.

Consumer Non-enhanced Results and Discussion

Descriptive statistics for fresh pork loin quality attributes, WBS tenderness at each end-point cooked temperature, and arithmetic mean consumer responses are presented in Table 1. Loins were selected to capture the range and combination of attribute values; therefore, these values in Table 1 are not expected to represent an industry average.

Table 1. Characterization of loin quality attributes and consumer response variables for non-enhanced loins served in consumer preference testing studies.

Trait	N	Mean	Std. Dev.	Range
Ultimate pH	679	5.76	0.23	5.34 – 6.50
Minolta L*	679	52.82	4.28	40.91 – 65.4
Minolta a*	679	17.42	1.38	11.70 – 21.02
Minolta b*	679	5.14	1.34	1.93 – 10.6
NPPC Color[a], 1 to 6	679	3.13	1.01	1.00 – 5.00
Intramuscular fat, %	678	3.06	1.37	0.43 – 6.93
NPPC Marbling[a], 1 to 6	679	2.52	1.27	1.00 – 6.00
Loin Purge Loss, %	679	1.97	1.92	-4.05 – 10.62
Warner Bratzler Shear, kg				
Cooked temperature				
62.8° C	678	2.51	0.60	1.26 – 4.97
68.3° C	676	2.64	0.76	1.23 – 6.84
73.9° C	677	2.75	0.78	1.24 – 7.01
79.4° C	675	2.88	0.85	1.46 – 6.43
Consumer Response Variables[2]				
Overall Dislike/Like	13190	4.84	1.87	1 – 8
Juiciness Dislike/Like	13232	5.15	1.89	1 – 8
Juiciness Level	13235	5.07	1.91	1 – 8
Tenderness Dislike/Like	13237	4.92	1.97	1 – 8
Tenderness Level	13239	4.87	1.95	1 – 8
Flavor Dislike/Like	13234	4.47	1.92	1 – 8
Flavor Level	13242	4.21	1.94	1 – 8
Likelihood of Purchase[c]	13183	2.90	1.21	1 - 5

[a] National Pork Producers Council (NPPC) 2000 color and marbling standards.
[b] Consumer responses measured on an 8-point, end-anchored scale.
[c] Consumer responses measured on a 5-point scale.

Model effects and significance levels are presented in Table 2 for all dependent consumer variables and are included to provide a clear understanding of the final ordered logistical models used in the study. A major finding of the present study was that interactions among independent variables were not observed, nor were quadratic

Table 2. Ordered logistical regression model effects and significance levels for consumer loin eating quality response variables measured on non-enhanced pork loins[a]

	Consumer Response							
	Overall Like	Juiciness Like	Juiciness Level	Tenderness Like	Tenderness Level	Favor Like	Flavor Level	Likelihood of Purchase
Model Effect	*Prob*	*Prob*	*Prob*	*Prob*	*Prob*	*Prob*	*Prob*	*Prob*
Cooked temperature	0.025	0.000	0.000	0.000	0.000	0.556	0.063	0.000
Intramuscular fat, %	0.000	0.001	0.010	0.018	0.049	0.049	0.000	0.000
pH	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.000
Minolta L*	0.650	0.303	0.237	0.246	0.122	0.838	0.102	0.224
Warner Bratzler Shear, kg	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

[a]Packing plant of loin origin and differences among consumer test cities are accounted for in the ordered logistic regression.

Table 3. Phenotypic correlations between consumer response variables (n = ~13,220 responses) assessing eating quality of non-enhanced pork loins.

	Consumer Response Variable						
Item	Overall Like	Juiciness Like	Juiciness Level	Tenderness Like	Tenderness Level	Flavor Like	Flavor Level
Juiciness Like	0.75	-					
Juiciness Level	0.65	0.87	-				
Tenderness Like	0.73	0.75	0.70	-			
Tenderness Level	0.68	0.71	0.71	0.92	-		
Flavor Like	0.79	0.63	0.54	0.62	0.58	-	
Flavor Level	0.71	0.57	0.52	0.55	0.53	0.88	-
Likelihood of Purchase	0.78	0.64	0.58	0.68	0.65	0.75	0.70

effects of independent variables found to be significant. A lack of interaction and quadratic effects and the overall large size of the study allowed for small differences among independent variables in this large sample population to be statistically significant. Interpretation of results in relation to the practical value of some significant effects observed will be provided. The data from the present study, designed to assess and test loin quality indicators in combinations, clearly indicate that the impact of the individual quality indicators on consumer acceptability measures were linear across the respective ranges. In addition, lack of quality measurement interactions implies that there is no evidence of dependencies among the independent variables that influence consumer responses, nor do any of the quality measures evaluated appear to have threshold levels that influence consumer perception of eating quality characteristics. Therefore, results of analyses reported in the present study reflect independent effects of incremental changes in a specific independent variable while maintaining all other model effects at their respective mean values.

Of note, across all consumer response variables, loin L*, a* and b* and visual color measurements did not directly contribute significantly to variation in consumer responses. However, the effect of L* was maintained in all models for consistency of reporting results across traits and because the original project design included fresh pork color as a primary selection criteria for assessment of pork eating quality.

A summary of correlations (Table 3) among consumer response variables indicates that relationships between like and level respectively for tenderness ($r = 0.92$), juiciness ($r = 0.87$) and flavor ($r = 0.88$) were strong and that consumers were consistently assessing like and level for each attribute evaluated. In addition, the observed strong relationships between like and level measures within a variable are directly reflected in similar statistical regression model relationships. Relationships between consumers rating of Overall-Like were strongest in relation to Tenderness-Like (r = 0.73), Flavor-Like (r = 0.79) and Likelihood of Purchase (r = 0.78) and somewhat weaker with respect to Juiciness-Like (r = 0.65). Moderate relationships (r = 0.52 to 0.62) were observed between the consumer's perceptions of Flavor-Like or Flavor-Level when compared with tenderness (like or level) and juiciness (like or level) ratings. Interestingly, the greatest individual attribute relationship with likelihood of purchase was observed for the consumer rating of pork Flavor-Like (r = 0.75) an indication that the more flavorful the pork, the greater likelihood that the consumer indicated they would purchase the pork.

Consumer Non-enhanced Cooked Temperature Effects

Table 4 describes the predicted mean responses for each consumer response variable at the four end-point cooked temperatures. Predicted mean responses for consumer variables on the 8-point response scale were very close to a score of five for each temperature evaluated, a consumer rating very near or slightly above the first increment on the favorable side of the response surface. This finding indicates that, regardless of end-point cooked temperature, consumer responses were marginal with respect to their perception of how they liked the non-enhanced pork served. Temperature effects were of practical significance for responses to a consumer's like and level of both juiciness and tenderness where incremental (5.5° C) increases in cooked temperature resulted in observable and practical (approximately 0.09 to 0.16 unit effect) reductions in the consumer's response rating. These results clearly indicate that, when assessing non-enhanced pork, cooking to a lower degree of doneness improved how well consumers liked the juiciness and tenderness of the pork they consumed. Temperature effects, while significant for the response to the question of Overall-Like (a combination of juiciness, tenderness and flavor), were not of a magnitude that was informative, representing only a 0.10 unit decrease in consumer response when comparing the least to greatest cooked temperature. Cooked temperature did not have an influence on either Flavor-Like or Flavor Level ratings in the present study which is supported by research (Prestat, Jenson, McKeith, and Brewer, 2002) for non-enhanced pork loins cooked at 70 or 80 ° C. Of note, predicted mean responses for Flavor-Like and level were also consistently less than mean consumer responses for the remaining assessment variables at each cooked temperature evaluated, indicating consumers had a somewhat poor perception of flavor or that the flavor of the pork offered did not meet expectations. Likelihood of purchase results were reflective of consumer palatability attribute responses, with consumers responding on average in a very neutral or non-committal manner and showing only a small incremental (0.12 unit) reduction in predicted response as cooked temperature increased across the full range. Based on the results presented, reducing the recommended cooking temperature of non-enhanced chops to either 62.8 or 68.3 ºC would improve consumer perceptions of juiciness and tenderness as individual attributes, but have little or no value in improving a consumer's overall perception of how well they like pork or the flavor of pork.

Table 4. Predicted[a] mean consumer responses for non-enhanced pork loins at designated loin end-point cooked temperatures.

		Cooked Temperature, ºC			
Variable[b]	Sig.	62.8	68.3	73.9	79.4
Overall Like	0.025	4.97	4.93	4.90	4.87
Juiciness Like	0.000	5.43	5.28	5.13	4.97
Juiciness Level	0.000	5.45	5.23	5.01	4.79
Tenderness Like	0.000	5.10	5.00	4.91	4.82
Tenderness Level	0.000	5.06	4.94	4.83	4.71
Flavor Like	0.556	4.56	4.55	4.54	4.54
Flavor Level	0.063	4.35	4.32	4.29	4.26
Likelihood of Purchase[c]	0.000	3.01	2.97	2.93	2.89

[a] Modeled effects with independent variables loin pH, intramuscular fat percentage, Minolta L* color, and Warner-Bratzler Shear force at their respective mean values, and after adjustment for the city where consumer testing was conducted.
[b] Consumer responses measured on an 8-point, end-anchored scale.
[c] Consumer responses measured on a 5-point scale.

Consumer Non-enhanced Intramuscular Fat Effects

Predicted mean consumer responses, represented at 1% increments for IMF, are presented in Table 5. Consumer responses increased in a significant linear fashion for all consumer response variables across the range of IMF evaluated; however, the increase in response per percentage change in IMF was generally very small, particularly for juiciness and tenderness related responses. The impact of IMF on both Overall-Like and Flavor Level appear to be of practical industry use only when comparing the highest (6% IMF) with the lowest (1% IMF) means responses. These findings support recent research by Rincker et al. (2008) who reported that IMF had no practical impact on eating quality of pork chops. The impact of increasing IMF on consumer probability of purchase, while significant, was also small with responses centered on neutrality, again offering insight that the consumer attitudes toward pork in the present study were indifferent with respect to changing levels of intramuscular fat.

Table 5. Predicted[a] mean consumer responses for non-enhanced pork assessed at designated loin intramuscular fat percentages.

	Intramuscular Fat, %					
Variable[b]	1	2	3	4	5	6
Overall Like	4.79	4.85	4.91	4.97	5.03	5.09
Juiciness Like	5.14	5.16	5.20	5.24	5.28	5.32
Juiciness Level	5.06	5.09	5.12	5.15	5.18	5.21
Tenderness Like	4.90	4.93	4.96	4.99	5.02	5.05
Tenderness Level	4.84	4.86	4.88	4.91	4.93	4.96
Flavor Like	4.40	4.47	4.54	4.62	4.69	4.76
Flavor Level	4.13	4.22	4.30	4.38	4.46	4.54
Likelihood of Purchase[b]	2.86	2.90	2.95	2.99	3.03	3.07

[a] Modeled effects with independent variables loin cooked temperature, pH, Minolta L* color, and Warner-Bratzler Shear force at their respective mean values, and after adjustment for the city where consumer testing was conducted.
[b] Consumer responses measured on an 8-point, end-anchored scale.
[c] Consumer responses measured on a 5-point scale.

While the highest levels of IMF were preferred when compared with the lowest levels evaluated in the present study, the cost associated with moving populations of pigs from lower to the upper end of the IMF range is not economically feasible at the commercial production level. Targeted markets, capitalizing on identified quality attributes and based on customers who are willing to pay a premium for improved quality, may see an economic advantage in the production of pork with high levels of intramuscular fat.

Consumer Non-enhanced Ultimate pH Effects

The effects of incremental increases in ultimate pH from a base of 5.40 to the upper level of 6.40 on predicted mean consumer responses (Table 6) demonstrate considerable differentiation in consumer responses and more pronounced effects across the pH range for all consumer response criteria when compared with either cooked temperature or IMF effects. In particular, for Juiciness- and Tenderness-Like and Level, consumer response increased by a full 1.0 increment when increasing from a pH of 5.4 up to 6.4. Ultimate pH is related to water holding capacity (Aberle, Forrest, Gerrard & Mills, 2001) and cook loss (Lonergan, Stalder, Huff-Lonergan, Knight, Goodwin, Prusa, & Beitz, 2007) which supports the observation that the consumers rated pork with greater ultimate pH more favorably for Juiciness-Like and Juiciness-Level.

Table 6. Predicted[a] mean consumer non-enhanced pork loin eating quality responses reported at designated pork loin pH levels.

	pH					
Variable[b]	5.40	5.60	5.80	6.00	6.20	6.40
Overall Like	4.69	4.81	4.94	5.07	5.19	5.31
Juiciness Like	4.84	5.04	5.24	5.43	5.62	5.81
Juiciness Level	4.71	4.94	5.16	5.38	5.59	5.80
Tenderness Like	4.59	4.79	4.99	5.19	5.39	5.58
Tenderness Level	4.47	4.70	4.93	5.15	5.37	5.59
Flavor Like	4.37	4.47	4.57	4.66	4.76	4.86
Flavor Level	4.20	4.26	4.31	4.37	4.43	4.49
Likelihood of Purchase[c]	2.82	2.89	2.96	3.03	3.10	3.17

[a] Modeled effects with independent variables loin cooked temperature, intramuscular fat percentage, Minolta L* color, and Warner-Bratzler Shear force at their respective mean values, and after adjustment for the city where consumer testing was conducted.
[b] Consumer responses measured on an 8-point, end-anchored scale.
[c] Consumer responses measured on a 5-point scale.

Predicted mean responses for Overall-Like and Flavor-Like increased across the pH range by approximately 0.5 unit indicating consumers rated pork with greater pH more favorably than the baseline 5.40 ultimate pH.   When viewed across all consumer response variables, the results of the present study suggest ultimate pH plays a large impact on consumer perceptions of pork eating quality and that the industry can expect reduced consumer satisfaction for products that are near an ultimate pH of 5.40 and greater overall satisfaction at any level greater than 5.40. Supporting this finding is the significant increase in a consumer’s rating for likelihood of purchase when ultimate pH increased from 5.4 to 6.4. Unfortunately, while a tremendous amount of research has been completed in an attempt to better understand how and what determines loin ultimate pH, no definitive strategy has been identified to consistently increase loin pH to the mean level, much less the upper level of pH described in the present study, making recommendations for increasing pH somewhat tenuous

Consumer Non-enhanced Warner-Bratzler Shear Effects

The relationship between WBS and consumer perceptions of pork clearly indicate that as WBS increased consumer ratings decreased from a very neutral rating for chops with the least WBS to a very unfavorable level at the greatest WBS level (Table 7). Consumer ratings of Tenderness-Like and Level, when directly compared to a mechanical measurement of WBS from a chop from the same loin cooked to the same degree of doneness, showed that consumer ratings averaged 5.0 or greater when WBS was ≤ 2.5 kg, a value near the average of the pork measured in the present study. Consumer ratings for tenderness ratings, averaged near 4.10 when WBS reached a level of 4.0 kg, and declined to an average rating near 3.0 when WBS reached 6.0 kg. Correlations between WBS and consumer rating for Tenderness-Like (r = -0.27) and Tenderness-Level (r = -0.29) were only moderate in the present data set, but were indicative of the associated decline in consumer ratings as WBS increased. Unfortunately, the medium to low correlation between a consumer assessment of tenderness and the attempt by scientists to estimate tenderness using mechanical methodology also implies that causal relationship between these techniques would also be relatively weak. With regard to tenderness of non-enhanced pork, the ability to achieve an average response that was one full unit on the favorable side of the consumer response scale (5) required a WBS level of ≤ 25 kg which is similar to the mean WBS of the non-enhanced pork cooked at 62.8° C, the lowest cooked temperature evaluated in the present study. A very similar pattern of consumer response change with increased WBS was observed for Overall-Like, Juiciness-Like and Juiciness-Level, whereby loins with WBS of less than 25 kg provided an average consumer response of ≥ 5 on the 8-point scale.

Table 7. Predicted[a] mean consumer responses for non-enhanced loins measured at designated loin Warner-Bratzler Shear force levels.

	Warner Bratzler Shear, kg									
Variable[b]	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
Overall Like	5.36	5.10	4.99	4.80	4.61	4.41	4.22	4.03	3.83	3.64
Juiciness Like	5.69	5.49	5.28	5.07	4.86	4.64	4.42	4.21	3.99	3.77
Juiciness Level	5.63	5.42	5.21	4.99	4.77	4.54	4.32	4.10	3.87	3.66
Tenderness Like	5.64	5.36	5.07	4.78	4.48	4.18	3.89	3.60	3.32	3.06
Tenderness Level	5.61	5.31	5.01	4.69	4.38	4.07	3.77	3.47	3.19	2.92
Flavor Like	4.86	4.73	4.60	4.47	4.33	4.20	4.07	3.94	3.81	3.68
Flavor Level	4.57	4.46	4.35	4.23	4.12	4.01	3.90	3.79	3.68	3.57
Likelihood of Purchase[c]	3.23	3.11	2.99	2.88	2.76	2.64	2.52	2.41	2.30	2.19

[a] Modeled effects with independent variables loin cooked temperature, pH, intramuscular fat percentage, and Minolta L* color at their respective mean values, and after adjustment for the city where consumer testing was conducted.
[b] Consumer responses measured on an 8-point, end-anchored scale.
[c] Consumer responses measured on a 5-point scale.

Predicted mean responses for Flavor-Like and Flavor-Level ratings were generally less across the range of WBS observed in the present study, having means of less than 5 and relatively small incremental decreases as WBS increased. This finding was consistent with respect to the consumer perceptions of flavor being very neutral and also indicating flavor and tenderness relationships are weak in the present study. Correlations between WBS and consumer Flavor-Like (r = -0.13) and Flavor-Level (r = -0.12) were generally low, validating the weak relationship between mechanical tenderness and consumer perception of pork flavor characteristics. The decrease in likelihood of purchase as WBS increased reinforces the consumer's negative perception of tough pork and challenges the pork industry to address tenderness in any efforts to increase consumer satisfaction.

The large incremental changes in consumer responses that reflect the sizable changes in WBS tenderness that were observed in the present study provide strong evidence that tenderness is one of the primary contributors to a consumer's perception of pork eating quality. Predicting pork tenderness in a fresh state is currently not possible and the use of WBS as an indicator, while possessing a moderate relationship with consumer assessment of tenderness, requires too much time and product loss to be used in a practical and timely marketing system. Of the currently measured fresh pork quality indicator traits evaluated in the present study, loin pH had the largest correlation of any trait measured in the current study with WBS (r = -0.29). However, whole the correlation is indicative of a linear association between the two variables, the causal influence is relatively hard to predict.

Consumer Non-enhanced Patterns of Response

To better describe the impact of incremental changes in consumer responses for the set of independent quality indicators evaluated in the present study, the authors chose to look closely at the consumer responses of six or greater on the eight-point scale. Data supplied in Table 8 summarize each consumer response variable and the modeled impact of incremental changes in temperature, IMF, pH and WBS for each variable. A response level of six or greater represents a numerically positive eating experience and assessing this segment of consumer responses may more clearly

Table 8. Frequencies of predicted consumer pork loin eating quality response levels observed across pork quality measures of intramuscular fat, ultimate pH, and Warner-Bratzler shear force and representing four cooked temperatures.

			Predicted Percentage of Consumers Rating Pork ≥ 6 (8-point scale)		Average % improvement in consumer rating per increment
Consumer Response Independent Variable	Increment	Range	% at minimum of the range	% at maximum of the range	
Overall Dislike/Like					
Cooked Temperature	5.5 °C	62.8 - 79.4 °C	42.8	40.5	- 1.0
Intramuscular Fat	1.0 %	1.0 – 6.0 %	38.8	45.8	1.4
Ultimate pH	0.20 units	5.40 – 6.40	36.4	51.3	3.0
Warner Bratzler Shear	0.50 kg	1.50 – 6.00 kg	52.6	17.4	4.0
Juiciness Dislike/Like					
Cooked Temperature	5.5 °C	62.8 - 79.4 °C	54.8	43.8	- 3.7
Intramuscular Fat	1.0 %	1.0 – 6.0 %	47.4	52.1	1.0
Ultimate pH	0.20 units	5.40 – 6.40	40.7	64.1	4.7
Warner Bratzler Shear	0.50 kg	1.50 – 6.00 kg	61.3	20.2	4.2
Juiciness Level					
Cooked Temperature	5.5 °C	62.8 - 79.4 °C	55.2	39.6	- 5.2
Intramuscular Fat	1.0 %	1.0 – 6.0 %	45.8	49.5	0.7
Ultimate pH	0.20 units	5.40 – 6.40	37.9	63.9	5.2
Warner Bratzler Shear	0.50 kg	1.50 – 6.00 kg	59.7	18.4	4.6
Tenderness Dislike/Like					
Cooked Temperature	5.5 °C	62.8 - 79.4 °C	46.7	40.2	- 2.1
Intramuscular Fat	1.0 %	1.0 – 6.0 %	42.1	45.6	0.6
Ultimate pH	0.20 units	5.40 – 6.40	35.4	58.2	4.6
Warner Bratzler Shear	0.50 kg	1.50 – 6.00 kg	59.5	11.4	5.3
Tenderness Level					
Cooked Temperature	5.5 °C	62.8 - 79.4 °C	45.1	37.4	- 2.5
Intramuscular Fat	1.0 %	1.0 – 6.0 %	40.0	42.2	0.6
Ultimate pH	0.20 units	5.40 – 6.40	32.2	57.8	5.1
Warner Bratzler Shear	0.50 kg	1.50 – 6.00 kg	58.4	9.3	5.5
Flavor Dislike/Like					
Cooked Temperature	5.5 °C	62.8 - 79.4 °C	34.5	34.0	- 0.2
Intramuscular Fat	1.0 %	1.0 – 6.0 %	31.1	38.9	1.5
Ultimate pH	0.20 units	5.40 – 6.40	30.6	41.0	2.1
Warner Bratzler Shear	0.50 kg	1.50 – 6.00 kg	41.1	18.8	2.5
Flavor Level					
Cooked Temperature	5.5 °C	62.8 - 79.4 °C	31.6	29.9	- 0.6
Intramuscular Fat	1.0 %	1.0 – 6.0 %	27.5	35.6	1.6
Ultimate pH	0.20 units	5.40 – 6.40	28.7	34.4	1.1
Warner Bratzler Shear	0.50 kg	1.50 – 6.00 kg	36.2	18.4	2.0

indicate where opportunities exist to improve pork eating quality. Incremental changes, specific to each loin attribute and cooked temperature, reflect the proportionate change in the percentage of consumers scoring pork ≥ 6 on the eight point scale and can be used to predict intermediate response levels for any given loin attribute presented.

Consumer responses for Overall-Like, a culmination of juiciness, tenderness and flavor attributes, indicated that as cooked temperature of the chop increased, the proportion of consumers rating pork as ≥ 6 decreased only marginally (~1% decline for each 5.5° C increase) and the predicted response would likely be of practical value only when comparing the ends (62.8 and 79.4° C) of the cooked temperature range evaluated. In contrast, incremental increases in cooked temperature had a large influence on consumer responses to Juiciness-Like and Level where > 50% of consumers rated pork as ≥ 6 when cooked temperature was 62.8° C followed by a proportionate decrease of 3.7 to 5.2% when cooked temperature increased incrementally by 5.5° C . The data clearly indicate that increased cooked temperature reduced juiciness, likely due to the increased moisture loss associated with the greater cooking time and cooked temperature. Increasing cooked temperature reduced the proportion of consumers rating pork ≥ 6 for both Tenderness-Like and Level at a magnitude intermediate (-2.1 to -2.5%) to responses for Overall-Like and juiciness attributes, and temperature had no impact in the present study on Flavor-Like or Level.

The influence of incremental changes in IMF on proportions of consumers rating pork as ≥ 6 were very small, ranging from 0.6% per 1% IMF for tenderness attributes up to 1.6% per 1% IMF for flavor level, effects that would only be useful when comparing the lowest (1% IMF) with the greatest (6% IMF) levels of the range evaluated in the present study. The small influence of IMF on consumer responses was also reflective of the very small correlations, ranging from 0.02 to 0.05, between IMF and individual consumer response variables and would support the findings of Rincker et al., (2008) who reported no influence of IMF on consumer or trained sensory attributes.

Ultimate pH and WBS in the present study were moderately and inversely correlated (r = - 0.29) indicating that as pH increased WBS values tended to decrease. While a correlation of this magnitude is not strong and may not imply cause and effect, the impact of both pH and WBS, as described previously in relation to mean responses, would suggest that this relationship has value if pH, collected in a plant, were used as one of a potential set of indicators that might be used to predict cooked product WBS or tenderness. The inverse relationship was also evident when assessing consumer responses at varying levels of ultimate pH and WBS. Favorable (greater) ultimate pH and WBS (lesser) levels were clearly associated with a greater proportion of consumers rating pork as ≥ 6 for all consumers attributes evaluated. Incremental increases in WBS (0.5 kg) resulted in a 4% decline in the proportion of consumer responses that were ≥ 6 in relation to their Overall-Like of the product, reducing the proportion of consumers from 52.6% at 1.5 kg WBS (very tender) to less than 20% responding at a level ≥ 6 when WBS reached 6.0 kg and representing a very tough pork product. As ultimate pH increased in 0.2 unit increments, Overall-Like of the pork increased by approximately 3% from a predicted base of 36.4% (pH = 5.40) to a level of 51.3% (pH = 6.40) for consumers ratings ≥ 6.   Juiciness-Like and level, contributors to the Overall-Like of the pork loins, were even more influenced by incremental changes in pH and WBS, with the predicted percentage of consumer responses ≥ 6 reaching > 60% at pH levels of 6.40

and grater than 59% when WBS values were 1.5 kg.   Similar to the observation for Overall-Like, incremental increases in WBS represented approximately a 4.2% decrease in consumer responses of ≥ 6, whereas for a 0.2 increase in ultimate pH, proportions of consumer responses that were ≥ 6 increased 4.7 to 5.2% when evaluating Juiciness-Like and level, respectively.

Relationships between a consumer's perception of tenderness and WBS, a mechanical estimate of expected consumer tenderness, were very pronounced in the present study. Predicted proportions of consumers rating pork Tenderness-Like and level at ≥ 6 were as large as 59.5% when the WBS values were equal to 1.5 kg, but were reduced dramatically (~ 5.5 %) for each incremental (0.5 kg) increase in WBS as illustrated in Figure 1. Consumers clearly disliked pork with greater WBS values; however, the challenge for the pork industry is determining where along the scale of WBS a product is deemed to be too tough as well as identifying a reliable method to assess tenderness in a pre-cooked, pre-purchase state that may allow product sorting and or price differentiation.

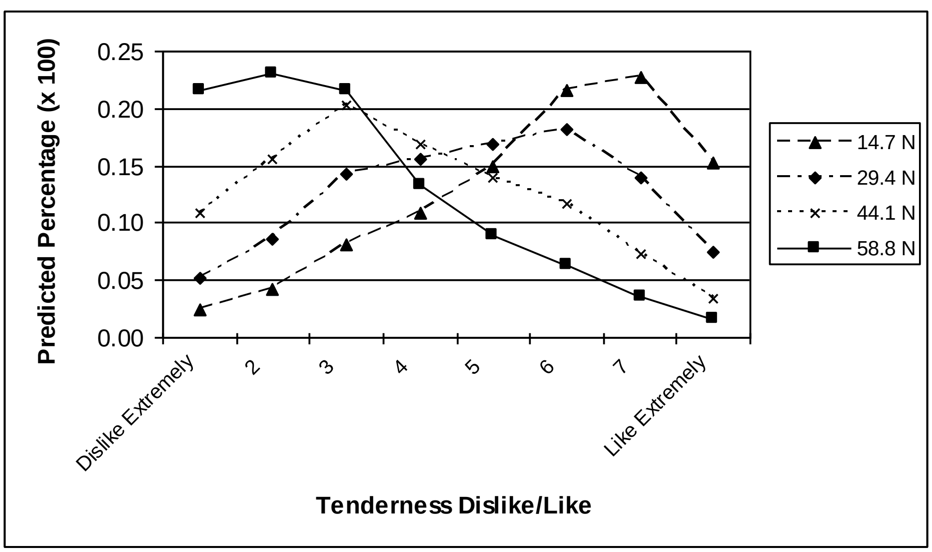


Figure 1. Illustration of the change in predicted percentage of consumer tenderness dislike/like responses at four Warner-Bratzler shear force levels.

In the present study, as ultimate pH increased from 5.4 to 6.4 the predicted proportion of consumer responses that were ≥ 6 for Tenderness-Like and level increased by ~23% to a level where nearly 58% of consumers would respond favorably (≥ 6 response) for pork with a pH of 6.40. Patterns of predicted consumer responses for Juiciness-Like (Figure 2) and level were similar to the relationship observed between pH and consumer perceptions of Tenderness-Like and level. When ultimate pH of pork was 5.40, consumers proportionately rated Juiciness-Like and level on the less desirable end of the scale, and as pH was incrementally increased the predicted proportion of consumers rating juiciness of pork as ≥ 6 increased by 4.7% (like) and 5.2% (level) for each 0.20 unit pH increase. While achieving an industry level ultimate pH of 6.4 would likely be very difficult, pH levels of 5.80 and 6.00 were predicted to improve the proportions of consumers rating Juiciness-Like and level at ≥ 6 by nearly 10% and 15%, respectively, when compared to an ultimate pH of 5.40.

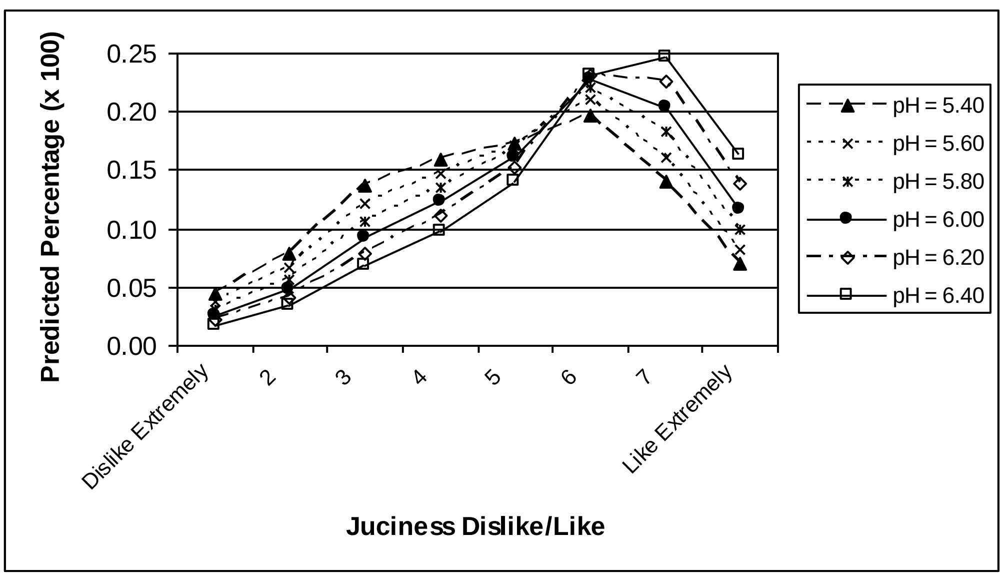


Figure 2. Illustration of the change in predicted percentage of consumer juiciness dislike/like responses at six ultimate pH levels.

Focusing on the proportion of consumers rating likelihood of purchase (Table 9) as ‘Probably Would Buy’ or ‘Definitely Would Buy’ (scores of 4 or 5 on a 5-point scale), data would suggest and support information in previous sections, that consumers are principally influenced by pH and WBS level and to a lesser extent by cooked temperature and IMF levels. Very tough pork had a very low likelihood of purchase, but even the average WBS pork served (~2.5 kg) would be predicted to achieve only a 34.3% likelihood of purchase. These findings support the influences of pH and WBS quality influences and relationships previously described and provide evidence for a very neutral to slightly negative overall perception of non-enhanced pork in general.

Table 9. Frequencies of predicted consumer responses to Likelihood of Purchase for across fresh pork quality levels for intramuscular fat, ultimate pH, and Warner-Bratzler shear force and representing four cooked temperatures.

			Predicted Percentage of Consumers Responding: Probably Would Buy or Definitely Would Buy the Pork		Average % improvement in consumer rating per increment
Consumer Response Independent Variable	Increment	Range	% at minimum of the range	% at maximum of the range	
Likelihood of Purchase					
Cooked Temperature	5.5 °C	62.8 - 79.4 °C	36.5	32.4	- 1.4
Intramuscular Fat	1.0 %	1.0 – 6.0 %	31.5	38.8	1.5
Ultimate pH	0.20 units	5.40 – 6.40	30.3	42.2	2.4
Warner Bratzler Shear	4.9 N	14.7 – 58.8 N	44.5	14.0	3.4

Consumer Non-Enhanced Conclusions

Consumer perceptions of pork eating quality were greatly influenced by and reflective of differences in fresh pork ultimate pH and cooked pork Warner-Bratzler shear force in the present study with significant, but smaller influences with respect to the level of loin intramuscular fat and end-point cooked temperature. The absence of significant interactions among quality indicators and between quality indicators and end-point temperature in the present data set suggests that, for non-enhanced pork loin, consumer's perceptions of eating quality (flavor, tenderness, juiciness, overall desirability) would be optimized in a fresh pork loin with greater pH and IMF, lower cooked WBS, and a chop that is cooked to a lesser degree of doneness.

Of general concern to the swine industry is the near neutral to unfavorable mean responses for consumer's perceptions of non-enhanced pork eating quality. This finding may reflect a significant industry challenge when pork competes with alternative protein sources for market share. Continued focus on production efficiency, carried out through improved genetics, nutrition, and facilities and necessitated by a requirement of financial sustainability, will likely provide obstacles to rapid improvement in non-enhanced pork eating quality. In concert with a production efficiency requirement, the findings of this consumer-focused study strongly suggest that additional research efforts that focus on the biological mechanisms that influence pork pH and tenderness are needed to improve pork palatability. In addition, identification of strategies for pork-chain intervention strategies to improve pork quality characteristics that influence consumer perception of non-enhanced pork are necessary to improve consumer demand.

Trained Sensory Panel - Non-enhanced Loin Results

Abstract

The study was designed to evaluate the interactive and individual effects of fresh pork loin (n = 679) ultimate ph (pH), intramuscular fat (IMF), Minolta L* color (L*), Warner-Bratzler shear force (WBS), and 4 cooked temperatures (62.8 °C, 68.3 °C, 73.9 °C, and 79.4 °C) on trained sensory perceptions of pork eating quality. Data were analyzed using logistical regression for dependent trained sensory variables of tenderness, chewiness, juiciness, fat flavor, lean flavor and saltiness. Increasing cooked temperature had the most pronounced negative influence on Juiciness Level responses which declined by 0.38 units for each 5.5° C increase in cooked temperature, and only a small negative influence on tenderness ratings and no influence on flavor or saltiness attributes. Shear force, of the traits assessed, had the greatest influence on sensory ratings. Increasing WBS by 0.50 kg resulted in a 3.7%, 1.8% for Tenderness and Juiciness ratings, respectively, but had no influence on flavor attributes. A quadratic effect of loin pH on ratings for tenderness, chewiness, and fat flavor indicated the adverse impact of loins with pH values of 5.40 and 5.60 on sensory ratings, with optimal pH of loins being from 5.80 to 6.40. Loin IMF and Minolta L* were significant but small contributors to variation in sensory responses, with observed effects have value when comparing the ends (1% vs. 6% for IMF, 46.9 and 65.0 units for Minolta L*) of each respective quality range. When assessing the results of the present study in total, shear force was the best indicator trait for assessing sensory properties of pork chops, followed by loin pH. Methods to identify tough pork prior to distribution and or processes to enable production of more tender pork are necessary to improve pork

eating quality. Current industry efforts geared toward measurement of loin pH likely have value and are best suited toward efforts to increase the mean level of loin pH upward in an effort to improve eating quality.

Trained Sensory Non-enhanced Statistical Models

Data were analyzed using ordered logistical regression through STATA software (StataCorp, LP, College Station, TX) and the output parameters summarized using CLARIFY V 2.1 (King, Tomz & Wittenberg, 2000). Dependent variables included trained sensory responses to ballot questions for chops representing non-enhanced loins only and representing product derived from three packing plants. Trained sensory data were assessed using a 10-point, end anchored intensity scale. Initial models tested the continuous independent variables cooked temperature, pH, IMF, L*, and WBS as linear and quadratic effects, and the two-way interactions among independent variables were tested. Plant of origin and trained sensory panel were included as independent effects. Model solutions were used to estimate mean response levels and predicted trained sensory response proportions for, and encompassing the range of, each independent variable in the regression model. Correlation statistics were used to describe linear relationships among variables of interest.

Trained Sensory Non-enhanced Results and Discussion

Descriptive statistics for fresh pork loin quality attributes, WBS tenderness at each end point cooked temperature, and mean trained sensory panel responses for each panel are presented in Table 1. Classification and sorting procedures utilized in the study appear to have adequately partitioned loins among the trained panels as mean, standard deviation and ranges evaluated were very similar across the two trained panels. Trained panel differences were observed in mean responses to nearly all ballot questions, justifying the inclusion of panel effects in statistical models. Fat Flavor Level mean levels were very near 2 on the 10-point scale, with sensory panelists realistically using scores of 1, 2 or 3, with very few scores between 4 and 7 on the 10-point scale. These data suggest that trained panelists observed very little fat flavor across the range of pork consumed in the study, and the results were consistent with the relatively low consumer scores for pork flavor previously described. Salt level mean response was near 1 (none) which was expected given that the non-enhanced chop samples were in a natural state and were served without any added ingredients.

A summary of significant ordered logistical regression model effects for all dependent trained sensory variables is provided in Table 2. For all dependent variables, the final models included independent effects of cooked temperature, IMF, pH, Minolta L*, and WBS regardless of significance levels within the model because these factors were the primary focus of the research project design. In the final statistical models for Juiciness Level and Fat Flavor Level, the quadratic pH effect was not significant and was therefore removed prior to estimating response means. A major finding of the present study was that interactions among independent variables were not observed for the trained sensory eating quality indicator responses tested, and with the exception of loin pH, no quadratic effects were observed. A very large sample size also allowed for smaller differences among some independent quality variables to be statistically significant. Interpretation as to the practical value of these small, but significant effects will be provided by the authors. Data from the present study do not indicate any pork quality measurement interactions, implying that there is no evidence of statistical dependencies among the independent variables that influenced the trained panel responses, nor did the quality measures evaluated appear to have threshold levels that influenced trained sensory perception of eating quality characteristics.

Therefore, results of analyses reported in the present study reflect independent effects of incremental changes in a specific independent variable while maintaining all other model effects at their respective mean values with the inclusion of loin pH as a quadratic effect only where the quadratic was significant. .

Correlations (Table 3) describing linear relationships among trained sensory measurements and between sensory responses and pork quality attributes observed in the present study reflect moderate, within panel relationships between Juiciness Level and Tenderness Level (r = 0.53), Chewiness Level (r = -0.43) and Lean Flavor Level (r = 0.38). Tenderness Level was highly, negatively correlated with Chewiness Level (r = -0.71) indicating tougher pork was also more chewy, a relationship that was expected to exist as both attributes reflect a panels attempt to evaluate meat structure. Of the relationships between sensory attributes and pork quality measures, the largest correlations were observed with pH in relation to Juiciness Level (r = 0.21) and tenderness level (r = 0.29) and for WBS in relation to Juiciness Level (r = -0.23), Tenderness Level (r = 0.41), and Chewiness Level (r =0.29), indicating loins with greater pH and lower WBS were rated by sensory panelists as more juicy and tender as well as less chewy. Direction of the correlations between Minolta L* and sensory attributes indicate that greater L* (paler) was associated with poorer Juiciness, Tenderness, and Chewiness Level ratings in the present data set.

Table 1. Characterization of loin quality attributes and trained sensory response variables for loins served in trained sensory preference testing studies.

Trait	Texas A&M n	Mean	Std. Dev.	Range	ISU N	Mean	Std. Dev.	Range
Ultimate pH	330	5.76	0.24	5.35 – 6.50	349	5.77	0.24	5.34 – 6.48
Minolta L*	330	52.77	4.42	40.9 – 65.4	349	52.87	4.15	41.74 – 64.40
Minolta a*	330	17.50	1.37	11.7 – 21.0	349	17.37	1.40	11.80 – 20.90
Minolta b*	330	5.09	1.36	1.93 – 10.60	349	5.19	1.38	2.05 – 9.40
NPPC Color[a], 1 to 6	330	3.13	1.04	1 – 5	349	3.12	0.99	1 – 5
Intramuscular fat, %	330	3.01	1.41	0.49 – 6.93	349	3.11	1.34	0.43 – 6.86
NPPC Marbling[b], 1 to 6	330	2.43	1.27	1 – 6	349	2.61	1.27	1 – 6
Loin Purge Loss, %	227	1.95	1.94	-4.05 – 10.62	349	1.96	1.88	-1.77 – 8.20
Warner Bratzler Shear, kg								
Cooked temperature								
62.8° C	329	2.54	0.60	1.29 – 4.91	349	2.47	0.58	1.26 – 4.97
68.3° C	333	2.70	0.82	1.40 – 6.83	343	2.58	0.69	1.23 – 6.49
73.9° C	326	2.78	0.79	1.23 – 6.08	351	2.73	0.76	1.33 – 7.02
79.4° C	327	2.90	0.89	1.52 – 6.39	348	2.85	0.81	1.46 – 6.43
Sensory Response Variables[b]								
Juiciness Level								
@ 62.8° C	1687	7.28	1.52	2 – 10	1695	6.45	1.61	1 – 10
@ 68.3° C	1668	7.07	1.51	2 – 10	1690	5.97	1.72	1 – 10
@ 73.9° C	1667	6.73	1.54	1 – 10	1689	5.41	1.88	1 – 10
@ 79.4° C	1691	6.44	1.55	1 – 10	1688	4.81	1.84	1 – 10
Tenderness Level								
@ 62.8° C	1686	7.32	1.42	2 – 10	1695	6.88	1.80	1 – 10
@ 68.3° C	1670	7.29	1.45	3 – 10	1690	6.58	1.84	1 – 10
@ 73.9° C	1669	7.19	1.50	2 – 10	1689	6.33	1.87	1 – 10
@ 79.4° C	1690	6.95	1.50	1 – 10	1688	6.12	1.81	1 – 10
Chewiness Level								
@ 62.8° C	1686	1.91	1.10	1 – 10	1695	2.84	1.33	1 – 9
@ 68.3° C	1668	1.88	1.11	1 – 9	1690	3.03	1.44	1 – 10
@ 73.9° C	1666	1.88	1.19	1 – 9	1689	3.22	1.56	1 – 10
@ 79.4° C	1689	1.99	1.32	1 – 10	1688	3.33	1.62	1 – 10

Fat Flavor Level								
@ 62.8° C	1686	1.53	0.62	1 – 7	1695	1.99	0.85	1 – 6
@ 68.3° C	1667	1.48	0.60	1 – 5	1690	1.98	0.83	1 – 6
@ 73.9° C	1667	1.47	0.57	1 – 5	1689	1.96	0.82	1 – 6
@ 79.4° C	1688	1.44	0.59	1 – 6	1688	1.98	0.80	1 – 7
Salt Level								
@ 62.8° C	1683	1.16	0.39	1 – 4	1695	1.01	0.17	1 – 7
@ 68.3° C	1665	1.15	0.39	1 – 6	1690	1.01	0.19	1 – 6
@ 73.9° C	1666	1.17	0.46	1 – 7	1689	1.01	0.15	1 – 6
@ 79.4° C	1686	1.16	0.42	1 – 7	1688	1.01	0.12	1 – 4
Lean Flavor Level								
@ 62.8° C	1687	5.69	1.13	1 – 8	--	--	--	--
@ 68.3° C	1668	5.71	1.11	1 – 8	--	--	--	--
@ 73.9° C	1669	5.70	1.15	1 – 8	--	--	--	--
@ 79.4° C	1691	5.72	1.17	1 – 8	--	--	--	--

[a] National Pork Producers Council (NPPC) 2000 color and marbling standards.
[b] Trained sensory responses measured on a 10-point, end-anchored scale.

Table 2. Ordered logistical regression model effects and significance levels for trained sensory eating quality response variables[a]

	Trained Sensory Response					
	Juiciness Level	Tenderness Level	Chewiness Level	Fat Flavor Level	Lean Flavor Level[b]	Salt Level
Model Effect						
Cooked temperature	0.000	0.000	0.813	0.014	0.222	0.854
Intramuscular fat, %	0.000	0.000	0.000	0.000	0.000	0.000
pH	0.000	0.000	0.000	0.000	0.003	0.001
Quadratic pH	NS[c]	0.000	0.000	0.000	NS[c]	0.002
Minolta L*	0.000	0.000	0.000	0.000	0.000	0.000
Warner Bratzler Shear, N	0.000	0.000	0.000	0.005	0.029	0.311

[a]Packing plant of loin origin and trained sensory panel (two panels used) destination effects were accounted for in ordered logistic regression models.
[b]Trained sensory characteristic measured only in only one trained sensory panel.
[c] NS = Not significant, effect removed from the final model.

Saltiness level arithmetic and model predicted mean responses presented are reflective of ≥ 98% of trained panelist responses being a ‘1’ on the 10-point scale. While salt may influence perceptions of flavor, the absence of saltiness in the present study should give additional support to the trained panel’s ability to differentiate fat and lean flavor relationships.

Table 3. Phenotypic correlations between trained sensory response variables and pork loin quality indicator traits (n = ~13,685 responses across two trained panels)

	Trained Sensory Response					
Item	Juiciness Level	Tenderness Level	Chewiness Level	Fat Flavor Level	Lean Flavor Level[a]	Salt Level
Tenderness Level	0.53					
Chewiness Level	-0.43	-0.70				
Fat Flavor Level	-0.02	0.01	0.13			
Lean Flavor Level	0.38	0.26	-0.41	-0.12		
Salt Level	0.07	0.03	0.01	0.13	0.02	
Intramuscular Fat, %	0.05	0.03	-0.03	0.09	0.03	NS
Minolta L*	-0.14	-0.15	0.10	-0.01	-0.06	0.07
pH	0.21	0.29	-0.16	0.14	0.07	-0.02
Warner Bratzler Shear, N	-0.23	-0.41	0.29	-0.09	NS	NS

[b]Trained sensory characteristic measured only in only one trained sensory panel.

Trained Sensory Non-enhanced Temperature effects

Trained panelists were able to detect measurable and statistically significant reductions in Juiciness Level ratings as cooked temperature increased. Incrementally, mean Juiciness Level responses declined by 0.38 units for each 5.5° C increase in cooked temperature, and the proportion of panelists responses predicted to be ≥ 7 on the 10-point scale were reduced from 46.3% at 62.5° C to 20% when cooked temperature was 79.4° C. Previously reported research (Heymann, Hedrick, Karrasch, Eggeman, and Ellersieck, 1990) also identified a reduction in juiciness scores from 5.4 to 4.2 on a 9-point scale when cooked temperature of pork roasts increased from 60 to

80° C. The reduction in Juiciness Level responses is consistent with an observed significant increase in the percentage cook loss (9.54 ± 0.17 % @ 62.8° C, 9.93 ± 0.17% @ 68.3° C, 10.98 ± 0.17% @ 73.9° C, and 12.50 ± 0.17% @79.4° C) as cooked temperature increased. Baublits, Meullenet, Sawyer, Mehaffey, and Saha (2006) and Torley, D'Arcy, and Trout (2000) reported that pork loin chops cooked to greater internal temperatures had more cook loss, resulting in a greater loss of meat juices and less juiciness.

Table 4. Predicted[a] mean trained sensory panel responses for the assessment of pork loin eating quality at four end-point cooked temperatures

	Cooked Temperature, ºC				
Variable[b]	Sig.	62.8	68.3	73.9	79.4
Juiciness Level	0.000	6.24	5.86	5.48	5.09
Tenderness Level	0.000	6.68	6.59	6.50	6.41
Chewiness Level	NS	3.05	3.05	3.05	3.05
Fat Flavor Level	0.014	1.99	1.97	1.96	1.94
Lean Flavor Level	NS	4.68	4.71	4.72	4.74
Saltiness	NS	1.01	1.01	1.01	1.01

[a] Modeled effects with independent variables loin pH, quadratic loin pH, intramuscular fat percentage, Minolta L* color, and Warner-Bratzler Shear force at their respective mean values, and after adjustment for packing plant of origin and trained sensory panel

Predicted mean sensory responses for Tenderness Level, observed across the cooked temperatures evaluated, were near 6.50 on the 10-point scale with > 47% of responses predicted to be ≥ 7 on the 10-point scale which is indicative of a slightly favorable assessment of the tenderness for the pork evaluated in the present study. Increasing cooked temperature from the least (62.8° C) to the greatest (79.4° C) temperature resulted in a 0.27 unit (2.7%) reduction in the predicted mean Tenderness Level rating, a change reflective of a small, yet significantly negative influence that greater end-point cooked temperatures have on pork tenderness ratings. Wood, Nute, Fursey, and Cuthbertson (1995) reported a 12.5% (1 unit) reduction in tenderness score on an 8-point scale as cooked temperature increased from 65 to 80° C which supports the direction of change noted in the present study but represents a much larger effect when compared with the observed impact in the present study. Cooked temperature had no impact on the Chewiness Level, a measure of sustained tenderness, in the present study.

Fat Flavor Level was not measurably influenced by cooked temperature of the chops. This finding may be a function of the distribution of trained sensory observation where ≥ 96% of ratings were ≤ 3 or may be a function of the relatively limited amount of cook loss observed at each end-point cooked temperature allowing fat flavor to be consistent across cooked temperatures. Lean Flavor predicted mean levels were near 4.70 in the present study and, similar to Fat Flavor Level, were not changed across the range of cooked temperatures evaluated. Wood et al. (1995) suggested that cooked temperature influenced sensory flavor intensity and that pork cooked to 80° C would be more flavorful than pork cooked to 72.5° C or 65° C end-point temperatures, but also reported that pork cooked to 72.5° C would be adequately juicy and more tender than pork cooked to 80° C, but more flavorful than chops cooked to 65° C.

In general, when comparing the impact of cooked temperature on eating quality across consumer and trained sensory studies, reducing the end-point cooking temperatures clearly improved the juiciness-related attributes to the largest extent, followed by marginal improvements in tenderness-related attributes. Both trained and consumer panels rated flavor-related attributes very similar across the range of cooked temperatures evaluated. These findings, associated only with non-enhanced pork loins, suggest that reducing the recommended cooked temperature for whole muscle pork products from the existing USDA guideline of 160 F (70 ºC) to either 145 º F or 155 ºF may improve acceptability of juiciness scores substantially while slightly improving tenderness. However, simply reducing cooked temperature did not overcome the negative effects associated with undesirable levels of fresh or cooked pork quality indicator traits such as pH and WBS.

Trained Sensory Non-enhanced Intramuscular Fat Effects

Increasing loin IMF by 1% improved predicted trained sensory Tenderness Level ratings by only 0.23 across the 1% to 6% range evaluated in the present study, representing a relatively small influence of IMF on perception of tenderness by trained panelists. At IMF levels of 1% and 6%, 50.7% and 57.4% of trained sensory responses were predicted to be ≥7 on the 10-point scale, respectively. Brewer, Zhu, and McKeith (2001) previously reported a 1 unit improvement in tenderness scores measured on a 5-point scale when comparing IMF levels of < 1% with IMF of ≥ 3.5%, while Rincker, Killefer, Ellis, Brewer and McKeith (2008) reported that intramuscular fat content has little influence on the eating quality of fresh pork loin chops. In agreement with the observed tenderness-IMF relationship, increasing IMF resulted in only a very slight reduction in the predicted mean response for Chewiness Level, whereby increasing IMF from 1 to 6% only improved Chewiness level by 0.19 units total.

Predicted mean responses for Juiciness Level increased by ~0.11 units for each 1% increasing in IMF, proving valuable when comparing the ends of the IMF range but of limited value when comparing 1% incremental increases in IMF.

Table 5. Predicted[a] mean trained sensory panel responses for the assessment of non-enhanced pork loin eating quality at six loin intramuscular fat percentage levels

	Intramuscular Fat, %					
Variable[b]	1	2	3	4	5	6
Juiciness Level	5.45	5.56	5.67	5.78	5.88	5.99
Tenderness Level	6.45	6.50	6.55	6.59	6.64	6.68
Chewiness Level	3.13	3.09	3.05	3.01	2.97	2.94
Fat Flavor Level	1.88	1.92	1.96	2.00	2.05	2.09
Lean Flavor Level	4.46	4.59	4.71	4.82	4.94	5.06
Saltiness	1.01	1.01	1.01	1.01	1.01	1.01

[a] Modeled effects with independent variables cooked temperature, loin pH, quadratic loin pH, Minolta L* color, and Warner-Bratzler Shear force at their respective mean values, and after adjustment for packing plant of origin and trained sensory panel effects.
[b] Trained sensory responses measured on a 10-point, end-anchored scale.

The association between intramuscular fat and flavor attributes was significant, but the effects were rather small in the present study and were at least partially due to a clustering of trained sensory responses near the lower, less intense, end of the evaluation scale. Increasing IMF in 1% increments improved the predicted mean Fat Flavor response by only 0.04 units and totaled ~ 0.21 units when comparing 1% with 6% IMF chops. Predicted mean Lean Flavor Levels increased by ~0.12 response units for each 1% increase in IMF and totaled ~0.60 unit improvement for a chop with 6% IMF when compared with 1% IMF. Fernandez, Monin, Talmont, Mourot, and Lebret (1999) suggested that there is a linear increase in pork flavor when assessing IMF levels of < 1% through 3.25%, but no relationship between flavor and IMF when IMF is > than 3.5%; however, their was no indication as to whether pork flavor measured in this study reflected fat and or lean flavor specifically.

Trained Sensory Non-enhanced Ultimate pH Effects

Ultimate pH was a primary factor influencing trained sensory responses in the present study, and predicted mean sensory scores were consistently less favorable for loins with pH values of ≤ 5.60. Trained sensory responses improved as pH increased to the upper end (pH = 6.40) of the pH range evaluated in the present study, suggesting trained panelist perceptions were most favorable at a loin pH near 6.40.

The effects of ultimate pH are reported in 0.20 unit increments across the range of pH evaluated. The predicted mean responses reported reflect the quadratic pH effect observed for trained sensory attributes of Tenderness Level, Chewiness Level and Fat Flavor Level and result in larger mean differences between consecutive pH classes as pH levels increase. For every 0.20 unit increase in pH, sensory responses for Juiciness Level (Table 6) increased by 0.23 scale units, resulting a 1.12 unit increase in the intensity of juiciness when comparing a chop with a 6.40 pH (mean = 6.38) with chop from a loin with a pH of 5.40 (mean = 5.26). When comparing the distribution of trained sensory responses across the range of pH values, 23.1% of responses were predicted to be ≥7 on the 10-point scale at a loin pH of 5.4 with the percentage increasing to 50.3% of responses at a loin pH of 6.40. Lonergan et al. (2007) reported juiciness ratings increased from 2.9 to 3.3 on a 10-point scale when comparing pork chops classified with a pH of < 5.50 to chops classified with a ph of > 5.95, an effect that was in agreement with but of a slightly smaller magnitude than observed in the present study.

Table 6. Predicted[a] mean trained sensory panel responses for the assessment of non-enhanced pork loin eating quality at six loin pH levels.

	pH					
Variable[b]	5.40	5.60	5.80	6.00	6.20	6.40
Juiciness Level	5.26	5.49	5.72	5.94	6.16	6.38
Tenderness Level	6.14	6.28	6.50	6.78	7.13	7.54
Chewiness Level	3.15	3.17	3.12	3.01	2.85	2.64
Fat Flavor Level	1.70	1.89	2.06	2.18	2.26	2.29
Lean Flavor Level	4.81	4.76	4.70	4.65	4.60	4.54
Saltiness	1.01	1.01	1.01	1.01	1.01	1.01

[a] Modeled effects with independent variables cooked temperature, intramuscular fat percentage, Minolta L* color, and Warner-Bratzler Shear force at their respective mean values, and after adjustment for packing plant of origin and trained sensory panel effects.
[b] Trained sensory responses measured on a 10-point, end-anchored scale.

Ultimate pH of the loin was also highly related to trained-panel sensory ratings for Tenderness Level with predicted mean responses increasing in a quadratic manner as loin pH increased. Increasing pH across the measured range of 5.40 to 6.40 resulted in an increase in the predicted mean response from 6.14 up to 7.54. The quadratic influence of loin pH changed the magnitude of incremental increases in predicted mean responses as pH increased from the least to the greatest level, indicating that a shift in pH from 5.40 to 5.60 (0.14 unit increase) had a lesser effect when compared with a shift from 5.60 to 5.80 (0.22 unit increase) or 6.00 to 6.20 (0.35 unit increase). Trained panelists clearly viewed chops from loins with greater pH as being more tender which was supported by a finding that 79.6% of trained responses were predicted to be ≥ 7 at a loin pH of 6.40 and only 41.3% at a loin pH of 5.40 across the 10-point assessment scale. Predicted mean chewiness ratings declined (less chewy) in a quadratic manner as pH increased resulting in a similar, positive manner as results for Tenderness Level, whereby the positive effects on mean chewiness scores were greater on the upper end of the pH range studied.

Predicted mean responses were greater for Fat Flavor when loin pH values were equal to or greater than 5.80 when compared with predicted means of loins with a pH of either 5.60 or 5.40 indicative of improved flavor as pH increased. Loins with pH values of ≥ 6.00 and had similar predicted mean responses for Fat Flavor, suggesting that trained panelists detected a slight plateau in the mean response toward the upper end of the pH range evaluated. In contrast, as loin pH increased trained ratings for Lean Flavor declined slightly (- 0.27 units) when observed across the 5.40 to 6.40 range evaluated. These findings indicate that greater pH levels allow for increased expression of fat flavor profiles when viewed by the trained panel and conversely that Lean Flavor was expressed to a lesser extent in chops from loins with a greater pH.

Trained Sensory Non-enhanced Warner-Bratzler Shear Effects

Trained sensory responses for the direct assessments of Tenderness Level and Chewiness Level as well as the associated responses were Juiciness Level and Lean Flavor Level were consistently less favorable as WBS of the non-enhanced loins increased in the present study (Table 7). Tougher pork was clearly identified by the panel and rated lower. In addition, tougher pork resulted in a negative association with the panel's perception of juiciness and lean flavor while having little or no influence on fat flavor.

Table 7. Predicted[a] mean trained sensory panel responses for the assessment of pork loin eating quality at loin Warner-Bratzler Shear force levels

	Warner Bratzler Shear, kg									
Variable[b]	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
Juiciness Level	6.10	5.92	5.74	5.56	5.37	5.19	5.00	4.82	4.63	4.45
Tenderness Level	7.46	7.08	6.70	6.31	5.91	5.50	5.09	4.69	4.29	3.91
Chewiness Level	2.39	2.64	2.93	3.25	3.59	3.97	4.37	4.80	5.23	5.69
Fat Flavor Level	1.99	1.98	1.97	1.96	1.94	1.93	1.92	1.90	1.89	1.88
Lean Flavor Level	5.30	5.05	4.81	4.56	4.32	4.07	3.82	3.58	3.31	3.08
Saltiness	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01	1.01

[a] Modeled effects with independent variables cooked temperature, loin pH, quadratic loin pH, intramuscular fat percentage, and Minolta L* color at their respective mean values, and after adjustment for packing plant of origin and trained sensory panel effects.
[b] Trained sensory responses measured on a 10-point, end-anchored scale.

At approximately the average WBS (2.67 kg) the predicted mean response was 6.70 units on the 10-point scale, a rating that increased to 7.46 when panelists assessed chops with the lowest WBS (1.5 kg). However, increasing WBS by 0.50 kg resulted in a reduction in the predicted mean Tenderness ratings by approximately 0.37 units for each incremental increase, reaching a point where the mean predicted response dropped to below 5.0 at a WBS value of 5.0 kg and reached a rating of less than 4.0 on the 10-point scale when WBS reached 6.0 kg. Graphically, the impact of WBS level on the percentage of trained sensory responses across the response surface (Figure 1) is evident in relation to the shift in response curves to the lower end of response scale as WBS increased. Using a rating of greater than 7 as a favorable response criterion, 77.8% of trained responses met the criteria if WBS was 1.5 kg, 57.9% of responses met the criteria at average WBS of the pork (~2.67 kg) and only 4.9% of responses met the criteria when WBS was 6.0 kg. Chewiness ratings followed a similar unfavorable trend as Tenderness ratings, whereby chops were chewier as WBS increased across the range evaluated.

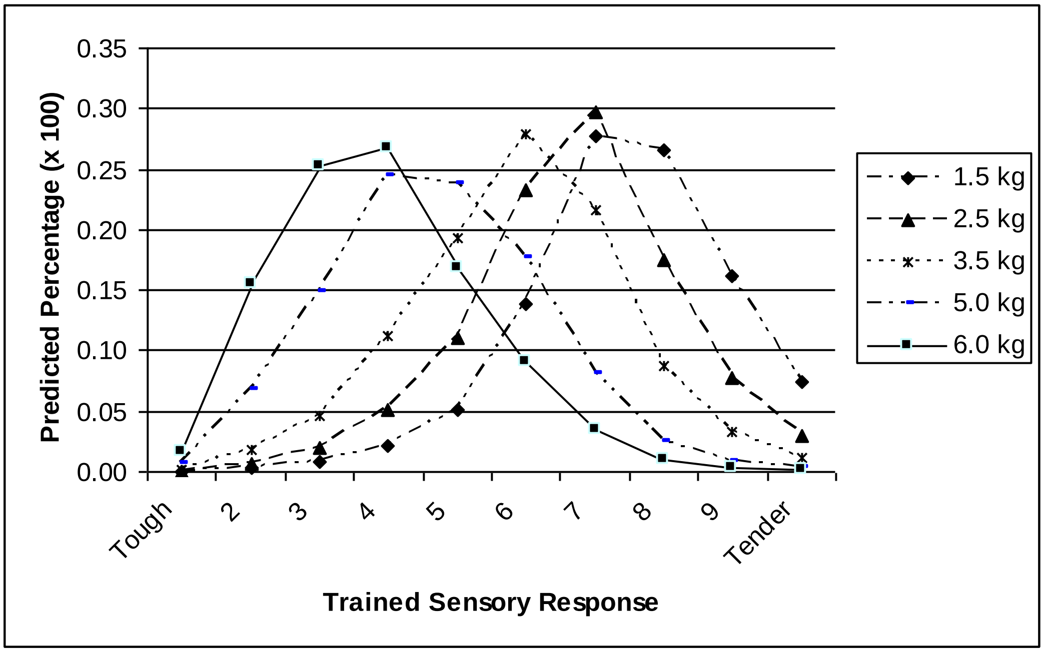


Figure 1. Illustration of the change in predicted percentage of trained sensory ratings for tenderness at five Warner-Bratzler shear force levels.

Incremental increases in WBS resulted in a 0.18 unit decrease in the predicted mean response for Juiciness ratings with the most tender (least WBS) chops having a mean of 6.10 units and the toughest (greatest WBS) chops having a predicted mean of 4.45 units.

Fat flavor was not influenced by WBS level, but Lean Flavor was rated as more desirable for chops with lower WBS. Incrementally increasing WBS by 0.5 kg resulted in a 0.25 unit reduction in trained sensory ratings for Lean Flavor resulting in an overall reduction in Lean Flavor of nearly 2.20 units when comparing the most tender to the toughest WBS classes.

Trained Sensory Non-enhanced Minolta L effects*

Trained sensory assessment of pork eating quality characteristics were influenced by Minolta L* levels in the present study, which is in contrast to the consumer portion of the present study where L* did not contribute to variation in consumer perceptions of eating quality. This contrast in results may be a function of the increased precision with which trained panels are able to differentiate theslight differences in sensory attributes that were present within the fresh pork color classes assessed. For illustration purposes, the Minolta L* values used to estimate predicted mean responses were chosen to approximately reflect the subjective visual color scores (NPPC, 2000) collected in the present data set. When substituted in the trained sensory statistical models for L*, the effect of visual color score was similar to that of L* in ordered logistical regression models. Accordingly, when assessing and comparing L* values with visual color scores, an L* reading between 61.9 and 65.0 closely represent a visual color score of 1 (pale pinkish gray to white), an L* of 57.9 represents a visual color score of 2 (grayish pink), an L* of 53.9 represents a visual color score of 3 (reddish pink), an L* of 49.9 represents a visual color score of 4 (dark reddish pink), and an L* of 46.9 represents a visual color score of 5 (purplish red) or 6 (dark purplish red).

When assessing the influence of L* color on predicted mean trained panel ratings (Table 8), greater loin L* measurements (values of 61.9 and 65.0) were consistently associated with less desirable responses, particularly when compared with chops derived from loins with L* values of ≤ 49.9 (darker color).   In comparisons between the ends of the L* range evaluated, Juiciness, Tenderness and Lean Flavor predicted means were reduced by 0.58, 0.27, and 0.78 units respectively, on the 10-point scale, while Chewiness increased (unfavorable) by 0.48 units on the same measurement scale. These findings suggest that pale pork was clearly rated less favorably than darker pork with the ‘normal’ colored pork rated intermediate to the ends of the range evaluated. Norman, Berg, Heymann, and Lorenzen (2003) reported that consumer perceptions of pork loins classified as 5 or 6 on the NPPC scale (NPPC, 2000) were improved for a measurement of 'liking of juiciness' when compared with visual color classifications of 4 or less, but no differences were observed across classifications for 'overall liking' or 'liking of flavor', and visual classification influences on 'liking of tenderness' were inconsistent across the color spectrum evaluated in that study.

Table 8. Predicted[a] mean trained sensory panel responses for the assessment of pork loin eating quality at designated loin Minolta L* levels

	Minolta L*					
Variable[b]	46.9	49.9	53.9	57.9	61.9	65.0
Juiciness Level	5.86	5.76	5.64	5.51	5.38	5.28
Tenderness Level	6.63	6.59	6.53	6.48	6.42	6.36
Chewiness Level	2.90	2.97	3.08	3.18	3.29	3.38
Fat Flavor Level	1.86	1.91	1.99	2.06	2.14	2.20
Lean Flavor Level	4.97	4.83	4.67	4.50	4.32	4.19
Salt Level	1.00	1.01	1.01	1.01	1.02	1.03

[a] Modeled effects with independent variables cooked temperature, loin pH, quadratic loin pH, intramuscular fat percentage, and Warner-Bratzler Shear force at their respective mean values, and after adjustment for packing plant of origin and trained sensory panel effects.
[b] Trained sensory responses measured on a 10-point, end-anchored scale.

The implications of trained sensory responses being influenced by fresh pork color while consumer responses are likely attributable to the increased precision with which trained panels are able to detect small differences. Because variation in loin L* information utilized within both the trained sensory and consumer panels was assessed across the biologically feasible range of both pH and IMF, it is difficult to interpret the L* effect as being simply a reflection of correlated response to changes in pH. The most important finding regarding L* in the present study is that very pale pork will produce less favorable juiciness, tenderness and chewiness ratings and reduce the limited Fat- and Lean Flavor observed in non-enhanced pork served.

Trained Sensory Non-Enhanced Conclusions

The influence of pork quality and cooked temperature on trained panel perception of eating quality varied for each of the descriptive attributes assessed within the present study. Increasing cooked temperature had the most pronounced negative influence on juiciness ratings and only a small negative influence on tenderness ratings, suggesting that a reduction in the recommended end-point cooked temperature will improve pork juiciness. Shear force, of the traits assessed, had the greatest influence on sensory ratings, whereby small increases (0.5 kg) in shear force resulted in large incremental, non-favorable changes in mean ratings for tenderness, chewiness, and an associated reduction in juiciness ratings. The quadratic effect of loin pH on ratings for tenderness, chewiness, and fat flavor indicated the adverse impact of loins with pH values of 5.40 and 5.60 on sensory ratings, while also suggesting that increasing pH will continue to improve sensory ratings, albeit in a smaller magnitude, as pH increases from 5.80 to 6.40. Based on data from the present study, systems that reduce the frequency of low pH (≤ 5.60 pH), and increase the proportion of loins with pH > 5.80 will greatly improve tenderness, juiciness, and fat flavor ratings of pork chops. Chops from loins that had relatively large amounts of intramuscular fat (6%) or from dark loins (Minolta L* = 46.9 units) were rated more favorably for juiciness, tenderness, chewiness and flavor attributes; however, the favorable response observed likely was of practical value when comparing with the opposite end of the respective range, rather than when describing small incremental changes in a given trait. When assessing the results of the present study in total, shear force was the best indicator trait for assessing sensory properties of pork chops, followed by loin pH. Methods to identify tough pork prior to distribution and or processes to enable production of more tender pork are necessary to improve pork eating quality. Current industry efforts geared toward measurement of loin pH likely have value and are best suited toward efforts to increase the mean level of loin pH upward in an effort to improve eating quality.

Consumer Sensory Panel - Enhanced and Non-Enhanced Pork Study

Abstract

The impact of variation in fresh pork loin Minolta L* (L*) color, intramuscular fat (IMF), ultimate pH (pH), and cooked Warner Bratzler shear force (WBS) on consumer (n = 2280) perceptions of palatability were assessed for non-enhanced (n = 228 loins) and enhanced (n= 227 loins; 10% pump, 0.35% Sodium Phosphate, 0.35% Salt, and 2.25% Potassium Lactate) chops cooked to four end-point cooked temperatures (62.8, 68.3, 73.9, and 79.4°C). Dependent consumer attributes were analyzed using ordered logistical regression techniques with model independent effects of enhancement treatment, cooked temperature, L*, pH, IMF, and WBS, testing linear, quadratic, and interactive effects among independent effects. Enhancement improved predicted mean consumer responses by approximately 0.90 to 1.20 units across the range of cooked temperature, pH, IMF and WBS attributes. Cooked temperature interacted with enhancement treatment whereby for non-enhanced chops predicted mean consumer ratings declined as cooked temperature increased, while, in contrast, for enhanced chops predicted mean consumer ratings either remained steady or improved as cooked temperature increased suggesting a need for differential cooking temperature recommendations. Minolta L* color did not contribute to variation in any consumer assessment of eating quality. Loin pH effects were quadratic for consumer ratings of overall like, juiciness like, tenderness like, flavor like, and preference related to likelihood of purchase with the greatest response observed for a loin pH of ≥ 5.80. Increasing intramuscular fat IMF had a significant, but very small positive influence on

consumer's acceptance of overall, juiciness, and flavor like, but did not contribute to variation in tenderness like. Across all consumer eating quality assessment response variables, increasing WBS led to the largest incremental reductions in consumer ratings of both enhanced and non-enhanced pork, suggesting that shear force plays a large role in consumer assessment of overall palatability.

Keywords: Palatability, Consumer, Enhancement, Tenderness, Pork Quality

Consumer Sensory – Enhanced and Non-Enhanced Statistical Models

Data were analyzed using STATA software (StataCorp, LP, College Station, TX) and an ordered logistic regression approach to predict probability estimates and mean responses for levels of independent variables tested. Dependent variables included consumer responses to ballot questions for both enhanced and non-enhanced loins originating from the same processing facility, representing only four of the eight product samples consumed by panelists. Preliminary models tested the continuous independent variables cooked temperature, pH of the fresh loin, IMF, L*, a*, b*, WBS, NPPC color, and NPPC marbling as linear and quadratic effects and the two-way interactions among independent variables. City of testing were included as independent effects. A linear covariate for the temperature treatment was tested in all analyses and found not significant but was maintained in all final models. Color values a* and b* were not significant effects and were removed from the final models. Final statistical models for all dependent variables included cooked temperature, temperature deviation, two-way interaction between cooked temperature and enhancement treatment, IMF, pH, quadratic effect of pH, L*, WBS, and city effects. Visual measures of loin color and marbling were substituted for L* and IMF, respectively to compare subjective visual and instrumental measures of lean color. Model solutions were entered into Clarify (King et al., 2000) to estimate mean response levels and predicted consumer response proportions for, and encompassing the range of, each independent variable tested. Linear correlations among dependent and independent effects were summarized using correlation statistics. Due to the strong correlations between like and level assessments observed in the present study, presentation of results from the present study will focus primarily on consumer perceptions of responses related to variables indicative of like/dislike which reflect more directly the consumer's expectations regarding eating quality of pork.

Consumer Sensory Panel – Enhanced and Non-Enhanced Results and Discussion

Consumer Sensory – Enhanced and Non-Enhanced Loin statistics

Descriptive statistics for sampled pork loin quality attributes for both enhanced and non-enhanced loins are presented in Table 1. Remembering that loins were selected to capture the range and combination of attribute values, these numbers are not expected to represent an industry average. These data show the goal of matching quality attributes across enhanced and non-enhanced pork loins was achieved for the fresh pork quality attributes evaluated.

A summary of significance levels for modeled effects across dependent consumer variables is provided in Table 2. Independent variables were maintained in final models as linear effects, even if not significant, to create standardization of interpretation across dependent variables. Of note, across all consumer response variables, loin L* did not contribute significantly to variation in any consumer responses; however, L* was maintained within final models because the original project design and existing industry quality assessment procedures often include color measurements as indicators of pork eating quality.

Table 1. Summary statistics for non-enhanced (n = 228) and enhanced (n = 227) loins served in consumer taste panels.

	Non-Enhanced				Enhanced			
Item	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
NPPC[a] color, 1 to 6	3.08	1.07	1.00	6.00	3.22	1.03	1.00	6.00
NPPC[a] marbling, 1 to 6	3.08	1.35	0.49	6.86	3.15	1.40	0.22	6.84
Ultimate pH	5.78	0.23	5.34	6.48	5.78	0.24	5.34	6.65
Minolta L*	53.77	4.45	43.80	65.40	53.13	4.51	41.00	67.50
Minolta a*	17.26	1.32	13.60	21.02	16.79	1.33	13.00	20.40
Minolta b*	4.44	1.03	2.00	6.80	4.34	1.08	2.00	7.30
Intramuscular Fat, %	3.06	1.34	0.49	6.86	3.15	1.40	0.22	6.84
Loin Purge, %	2.62	2.08	0.00	10.62	3.77	1.41	1.08	7.56
Post Pump pH	-	-	-	-	5.91	0.22	5.24	6.47
Warner Bratzler Shear, kg								
62.8° C	2.37	0.51	1.29	3.99	1.67	0.41	0.97	3.41
68.3° C	2.44	0.54	1.23	4.32	1.65	0.43	1.00	3.45
73.9° C	2.62	0.67	1.34	5.50	1.62	0.37	0.88	3.32
79.4° C	2.78	0.75	1.53	5.94	1.72	0.42	1.04	3.55

[a]National Pork Producers Council (NPPC) color and marbling standards (2000).

Table 2. Model effects and significance levels of ordered logistic regression analyses of consumer response variables for pork loin eating quality of non-enhanced and enhanced loins.

	Consumer Response Variable							
	Overall Like	Juiciness Like	Juiciness Level	Tenderness Like	Tenderness Level	Flavor Like	Flavor Level	Likelihood of Purchase
Model Effect	P-value	P-value	P-value	P-value	P-value	P-value	P-value	P-value
Cooked Temperature	0.364	0.000	0.000	0.011	0.001	0.929	0.261	0.005
Enhancement	0.000	0.000	0.000	0.000	0.000	0.013	0.000	0.000
Enh × Temp Interaction	0.008	0.000	0.000	0.007	0.233	0.000	0.000	0.000
Intramuscular Fat	0.000	0.002	0.255	0.287	0.231	0.041	0.000	0.004
Ultimate pH	0.000	0.000	0.000	0.004	0.007	0.000	0.025	0.008
Ultimate pH -quadratic	0.001	0.000	0.000	0.007	0.012	0.001	0.025	0.010
Minolta L*	0.423	0.892	0.143	0.167	0.430	0.617	0.924	0.094
Warner Bratzler Shear	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
City of Testing	0.000	0.000	0.000	0.181	0.039	0.000	0.000	0.005

Table 3. **A:** Correlations between consumer response variables for non-enhanced chops. **B:** Correlations between consumer response variables for enhanced chops.

	Consumer Response Variable[a]						
Consumer Response Variable	Overall Like	Juiciness Like	Juiciness Level	Tenderness Like	Tenderness Level	Flavor Like	Flavor Level
A: Non-Enhanced Loin							
Juiciness Like	0.74	1.00	-	-	-	-	-
Juiciness Level	0.64	0.88	1.00	-	-	-	-
Tenderness Like	0.72	0.75	0.69	1.00	-	-	-
Tenderness Level	0.66	0.71	0.70	0.91	1.00	-	-
Flavor Like	0.79	0.61	0.54	0.59	0.57	1.00	-
Flavor Level	0.71	0.55	0.51	0.54	0.52	0.88	1.00
Likelihood of Purchase[b]	0.77	0.65	0.58	0.67	0.64	0.76	0.71
B: Enhanced Loin							
Juiciness Like	0.74	1.00	-	-	-	-	-
Juiciness Level	0.58	0.79	1.00	-	-	-	-
Tenderness Like	0.74	0.73	0.64	1.00	-	-	-
Tenderness Level	0.63	0.65	0.69	0.83	1.00	-	-
Flavor Like	0.81	0.65	0.52	0.63	0.55	1.00	-
Flavor Level	0.72	0.59	0.54	0.56	0.54	0.87	1.00
Likelihood of Purchase[b]	0.81	0.67	0.53	0.68	0.59	0.78	0.72

[a] Consumer responses measured on a 8 – point end anchored scale, greater numbers signified a more favorable response.

An interaction effect was observed between enhancement treatment and cooked temperature for all consumer response variables, with the exception of Tenderness Level, with the interaction effect resulting in a slight change in the magnitude of the difference between enhanced and non-enhanced chops across the range of a given independent variable and in no cases were there changes in rank. Quadratic effects were observed for pH for all consumer response variables assessed, representing the only non-linear effects observed in the present study, and generally indicating a slight plateau effect for consumer responses as pH of the loins increased.

A lack of interactions among measured quality attributes suggests that the individual quality measurements evaluated in the present study are largely independent of the level of another measure of pork quality. Therefore, the consumer response results presented in tabular and graphical form within the manuscript reflect the impact of changing an individual independent quality variable in logical increments while holding all other independent model effects at their respective mean level. Also, while the greatest shear force value observed in the present study for enhanced chops was 3.57 kg, predicted consumer response ratings were projected beyond the maximum observed level using model estimates that reflect the range of WBS observed in the non-enhanced chops.

Correlations among consumer response variables (Table 3) demonstrate the strong linear associations between consumer responses. In addition, relationships between how well consumers like an attribute and the corresponding desired level of a given eating quality measure were very high, contributing to similarities in significance levels for model effects and trends and only slight differences in predicted mean responses between how well a specific attribute was liked and the corresponding perception of the level.

Consumer Sensory – Enhanced and Non-Enhanced, Enhancement Effects

Within the present study, enhancement of pork loins significantly improved all consumer responses associated with measurements of eating quality and likelihood of purchase. Because the objectives of the present study were focused on assessing the influence of pork quality and cooked temperature on consumer perceptions of eating quality in both enhanced and non-enhanced pork, the effects of enhancement are reported throughout the manuscript in relation to their respective influence within each of the primary pork quality indicators (IMF, pH, WBS) as well as cooked temperature main effects.

Consumer Sensory – Enhanced and Non-Enhanced Cooked Temperature Effects

A cooked temperature by enhancement interaction was observed for all consumer assessment variables with the exception of Tenderness Level (Table 4). The interactive effects were generally indicative of a change in the magnitude of the difference in predicted mean consumer responses when comparing enhanced and non-enhanced chops and were typically a function of a slight decline in predicted mean consumer ratings for non-enhanced chops as cooked temperature increased and either a slight improvement or no change in predicted mean consumer ratings for enhanced chops as cooked temperature increased. For all consumer descriptive attributes, non-enhanced pork chops received greater predicted mean ratings when cooked to the lowest (62.8° C) cooked temperature, an indication of the adverse impact of increasing cooked temperature on eating quality. In contrast for enhanced chops, the very small changes or increases in the observed predicted mean ratings across attributes suggest that enhancement offers protection from or may slightly improve eating quality when pork chops are cooked to a greater degree of doneness.

Across all cooked temperatures, predicted mean consumer ratings for Juiciness Like and Level were slightly greater than ratings for Tenderness Like and Level and much greater than ratings for Flavor Like or Level, indicating that consumers in general found juiciness-related attributes of the pork served more desirable than the other individual descriptive attributes, regardless of enhancement status. The predicted mean ratings for Overall Like, a culmination of juiciness, tenderness and flavor, were intermediate to the individual descriptive attributes means across the temperature range evaluated, reflecting the variation in individual attribute means contributing the overall assessment.

Table 4. Predicted[a] means for consumer assessment of pork eating quality measured on enhanced (E) and non-enhanced (N) pork loins cooked at four end-point temperatures (T).

		Cooked Temperature, °C							
		62.8		68.3		73.9		79.4	
Consumer Response[b]	Sig[c]	N	E	N	E	N	E	N	E
Overall Like	E, T×E	5.12	6.00	5.10	6.06	5.08	6.12	5.05	6.18
Juiciness Like	E, T, T×E	5.61	6.34	5.48	6.35	5.36	6.36	5.23	6.38
Tenderness Like	E, T, T×E	5.39	6.20	5.33	6.22	5.27	6.26	5.20	6.28
Flavor Like	E, T×E	4.61	5.71	4.61	5.77	4.61	5.84	4.60	5.91
Juiciness Level	E, T, T×E	5.63	6.39	5.45	6.35	5.27	6.31	5.08	6.28
Tenderness Level	E, T	5.43	6.33	5.35	6.30	5.27	6.26	5.18	6.23
Flavor Level	E, T×E	4.36	5.57	4.33	5.64	4.29	5.70	4.27	5.76
Likelihood of Purchase[d]		3.13	3.71	3.08	3.75	3.03	3.78	2.99	3.82

[a] Independent effect of cooked temperature with loin intramuscular fat, Minolta L*, ultimate pH, and Warner-Bratzler Shear Force modeled effects adjusted to their respective mean value.

[b] Consumer responses assessed using and end-anchored 8-point Hedonic Scale; Like variables: 1 = Dislike Extremely, 8 = Like Extremely; Juiciness Level, 1 = Extremely Dry and 8 = Extremely Juicy; Tenderness Level, 1 = Extremely Tough and 8 = Extremely Tender; Flavor Level, 1 = No Flavor and 8 = Extremely Flavorful.

[c] Significance = Main effect significance, $P < 0.01$; T = Temperature, E = Enhancement, T×E = Temperature×Enhancement Interaction

[d] 1 = Definitely Would Not Buy, 3 = May or May Not Buy, 5 = Definitely Would Buy.

When comparing enhanced with non-enhanced chops at the cooked temperature extremes of 62.8° C and 79.4° C, the predicted mean ratings for enhanced chops increased by 0.73 and 1.15 units respectively for Juiciness Like, 0.81 and 1.08 units respectively for Tenderness Like, 1.1 and 1.31 units respectively for Flavor Like, and 0.88 and 1.13 units respectively for Overall Like. Similar responses were observed for predicted means related to the Level of the corresponding descriptive attributes. Enhancement improved consumer ratings for Flavor Level and Flavor Like by the greatest absolute and percentage basis of the descriptive attributes assessed over the temperature range evaluated. The large effect may be related to the overall predicted means being lower for flavor-related attributes which allowed for the opportunity for additional upward movement along the 8-point scale when compared to attributes with greater predicted mean responses. A more likely reason is that the improved flavor was the direct result of the addition of salt to the product from within the enhancement brine as previously suggested by Vote et al. (2000), Prestat et al. (2002) and Keeton (1983), who have reported that salt from the brine solution increases the flavor profile and consumer perceptions of flavor. In either case, non-enhanced chops were clearly less flavorful and the effect of enhancement improved flavor perception substantially with an a larger impact as cooked temperature increased.

In relation to the descriptive attributes Juiciness Like and Level, juiciness ratings decreased on average 4.75% for non-enhanced chops and there was essentially no change in juiciness rating for enhanced chops as cooked temperature increased from

62.8 to 79.4º C. The interaction effect was similar to the observed response reported by Prestat et al. (2002) in a consumer assessment of juiciness in that the beneficial effect of enhancing meat products on juiciness ratings is most apparent when cooked to abusive temperatures. Dunlavy and Lamkey (1994) also reported that non-enhanced chops cooked to a higher internal temperature had lower juiciness ratings, while Heymann et al. (1990) reported a 13.5% reduction in juiciness ratings as cooked temperature increased from 65.5° C to 82.2° C and further suggested the decline was related to a decline in cooked moisture content of the product. In the present study, cooking loss was greater in non-enhanced chops (10.3%) when compared with non-enhanced chops (6.8%), at least partially explaining the differences in consumer perceptions of juiciness. Baublits et al. (2006) had previously reported that percent cooking loss decreased 11.4% when pork chops were enhanced, which supports the findings in the present study and suggests that the addition of salt and phosphate brine helped retain natural juices even at a high end-point temperature. Sheard et al. (1999) reported that enhancing pork with 5% polyphosphate brine injection improved juiciness ratings by 5.9%. Moreover, Prestat et al. (2002) reported an 8.3% improvement in juiciness rating for enhanced chops. In the present data set, enhancement improved chop juiciness ratings by 13% when loins were injected to a target 10% pump rate.

The interactive effects between enhancement and cooked temperature on Tenderness Like were related to the reduction in Tenderness Like ratings for the non-enhanced chops as temperature increased and no change in ratings for enhanced chops as temperature increased. The predicted decline in the mean rating for

Tenderness Like (-0.19 units, 2.5%) when increasing cooked temperature from 62.8 C to 79.4° C was small when compared with reports by Wood et al. (1995) who had reported a 12.5% reduction in tenderness ratings as cooked temperature increased from 65° C to 80° C for non-enhanced chops. The difference in predicted mean scores between enhanced and non-enhanced chops increased in magnitude of the 0.80 units at 62.8 C to 1.08 units at 79.4° C and is indicative of the enhancement process protecting against toughening at high end-point temperatures. Prestat et al. (2002) also reported an interaction between enhancement treatment and internal cooked temperature whereby tenderness remained constant as temperature increased for enhanced chops but declined in non-enhanced chops indicating the enhancement process offered protection against over cooking by consumers. Christensen et al. (2000) and Bouton and Harris (1972) reported that the increase in toughness measured across a similar range of cooked temperatures was the result of myofibrillar protein denaturation in non-enhanced pork.

The main effect of cooked temperature was not significant in the present study for either Flavor Level or Like, which is in contrast to the reports by Simmons et al. (1985) and Wood et al. (1995) who reported that increasing end-point temperature increases flavor intensity in pork. It is hypothesized that the increase in flavor intensity is mainly a result of the concentration of flavor components within the product, with Wood et al. (1995) reporting cook loss increased from 28.3% at 65º C and 41.4% at 80º C cooked temperatures, supporting a potential to increase flavor as a result of lower moisture levels when pork was cooked to greater temperatures. In the present study, percent cooking losses were 7.55% at 62.8 C, 8.03% at 68.3 C, 8.95% at 73.9 C, and 9.70% at 79.4 C, levels that were quite low and may suggest that the method of cooking (clam-style cooker, simultaneous heat on both sides) and related short cooking time may have contributed to the limited impact of cooked temperature on perceptions of Flavor Like and Level in the present study.

The cause of the small but consistent improvement in the mean response for the attribute Overall Like of enhanced chops as cooked temperature increased may have been related to either the observed improvement in flavor or the increased pH observed as a result of the enhancement process. In relation to the present study, consumer taste sessions were conducted under red lights which attempted to eliminate potential color differences in cooked chops due to differing degrees of doneness; however, differences in perception of grayness were noted by several consumers and expressed as questions regarding whether the pork was properly cooked, particularly in relation to enhanced pork served at the low degrees of doneness (62.8° C and 68.3° C). In response to these questions, all participants within a session where a question was asked were provided a standard response indicating that all pork was served at a temperature that was safe for consumption. While difficult to interpret, the perception of differences in grayness in enhanced pork cooked to the lower temperatures may have been interpreted as being undercooked and therefore may have resulted in slightly lower ratings. The authors have only observational data to support this hypothesis at the consumer level; however, the relationship between cooked chop appearance, particularly chops with ultimate pH near the upper end of the range evaluated in the present study, under standard lighting conditions may need to be investigated with respect to consumer desirability prior to making recommendations relative to an optimal cooked temperature.

The proportion of predicted responses of ≥ 6 on the 8-point scale were chosen by the authors as the criteria for representation of favorable response levels when comparing enhanced and non-enhanced chop treatments. For the descriptive attribute Overall Like, when measured at 62.8° C, 46.2% of consumers were predicted to rate non-enhanced chops as ≥ 6 on the 8-point scale, while 67.5% of consumers rated the enhanced chops at a similar level (Table 5). In addition, at each temperature evaluated, the proportion of consumer response ratings of 6, 7, or 8 for Overall Like were nearly equal (~ 23% in each category) for enhanced chops. In contrast, when comparing proportions of response ratings for Overall Like at each temperature in the non-enhanced chops, the negative shift in predicted mean ratings resulted in a sizable reduction in the proportion of predicted ratings of 6 (~ 20% of responses), 7 (~ 15.0% of responses) and 8 (~ 9.0% of responses), producing a shift in the distribution that resulted in a sizable increase in the proportion of responses that were less than 6 on the scale for non-enhanced chops.

Table 5. **A**: Predicted probability[a] of consumer response for Overall Like of non-enhanced chops cooked to four end-point temperatures. **B**: Predicted probability[a] of consumer response for Overall Like of enhanced chops cooked to four end-point temperatures.

A	Non-Enhanced Chops							
Cooked Temperature[b]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
62.8 °C	0.0361	0.0641	0.1096	0.1402	0.1879	0.2055	0.1570	0.0996
68.3 °C	0.0369	0.0653	0.1112	0.1415	0.1884	0.2043	0.1547	0.0976
73.9 °C	0.0377	0.0666	0.1129	0.1429	0.1888	0.2029	0.1525	0.0957
79.4 °C	0.0385	0.0679	0.1146	0.1442	0.1891	0.2015	0.1503	0.0939

B	Enhanced Chops							
Cooked Temperature[b]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
62.8 °C	0.0153	0.0289	0.0550	0.0834	0.1430	0.2202	0.2435	0.2106
68.3 °C	0.0143	0.0271	0.0519	0.0794	0.1383	0.2181	0.2489	0.2220
73.9 °C	0.0134	0.0254	0.0490	0.0755	0.1334	0.2156	0.2539	0.2338
79.4 °C	0.0125	0.0238	0.0462	0.0718	0.1286	0.2125	0.2584	0.2462

[a] To convert to a percent multiply probabilities by 100.
[b] Independent effect of cooked temperature with intramuscular fat, Minolta L*, ultimate pH, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

Predicted consumer distribution responses for Juiciness Like indicate that 58.6% of consumers were predicted to rate pork as ≥ 6 at 62.8° C, declining to 48.9% of consumers when temperature increased to 79.4 °C within non-enhanced pork comparisons (Table 6). In contrast, increasing cooked temperature had no influence on ratings for Juiciness Like for the enhanced chops, with over 76.0% of consumers predicted to rate enhanced pork juiciness like as ≥ 6 across cooked temperatures. When analyzing the distribution of predicted Juiciness Like ratings for non-enhanced chops, percentages peak at a rating of 6 and decline for ratings of 7 and 8, while the predicted percentage of consumer responses were greater and nearly equal for ratings of 6, 7, or 8 for enhanced chops. Data from the present study support lowering end-point cooked temperature as a means to improve consumer's perception of non-enhanced loin juiciness, but also suggest enhancement effects, at the level tested in the present study, surpassed the impact of reducing cooked temperature within the non-enhanced chops.

Table 6: **A**: Predicted probability[1] of consumer response for Juiciness Like of non-enhanced chops cooked to four end-point temperatures. **B**: Predicted probability of consumer response for Juiciness Like of enhanced chops cooked to four end-point temperatures.

A	Non-Enhanced							
Cooked Temperature[2]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
62.8 °C	0.0210	0.0405	0.0771	0.1100	0.1649	0.2336	0.2153	0.1376
68.3 °C	0.0238	0.0454	0.0852	0.1186	0.1716	0.2310	0.2013	0.1232
73.9 °C	0.0269	0.0509	0.0938	0.1271	0.1772	0.2266	0.1872	0.1102
79.4 °C	0.0305	0.0570	0.1030	0.1356	0.1816	0.2207	0.1732	0.0983

B	Enhanced							
Cooked Temperature[2]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
62.8 °C	0.0095	0.0190	0.0388	0.0619	0.1111	0.2111	0.2863	0.2623
68.3 °C	0.0094	0.0187	0.0382	0.0611	0.1099	0.2100	0.2872	0.2655
73.9 °C	0.0092	0.0184	0.0376	0.0603	0.1088	0.2089	0.2881	0.2688
79.4 °C	0.0091	0.0181	0.0371	0.0595	0.1076	0.2078	0.2889	0.2720

[1] To convert to a percent multiply probabilities by 100.
[2] Independent effect of cooked temperature with intramuscular fat, Minolta L*, ultimate pH, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

The distribution of predicted consumer ratings for Tenderness Like across the four cooked indicated that increasing cooked temperature from 62.8º C to 79.4º C decreased the proportion of consumer ratings of ≥ 6 from 54% to 49% when assessing only non-enhanced chops (Table 7). Enhancement increased the predicted proportion of consumer ratings of ≥ 6 when compared with non-enhanced chops with 72.4% and 74.2% of consumer ratings predicted to be either a 6, 7, or 8 at 62.8º C and 79.4º C cooked temperatures respectively. Proportions of consumers responses for Tenderness Level were of a similar magnitude as those observed for Tenderness Like;

however, the interaction between cooked temperature and enhancement was not significant which resulted in similar, small reductions (5% for non-enhanced, 2% for enhanced) in the predicted proportions of consumer responses when comparing 62.8º C and 79.4º C cooked temperatures.

Table 7. **A**: Predicted probability[1] of consumer response for Tenderness Like of non-enhanced chops cooked to four end-point temperatures. **B**: Predicted probability of consumer response for Tenderness Like of enhanced chops cooked to four end-point temperatures.

A	Non-Enhanced							
Cooked Temperature[2]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
62.8 °C	0.0293	0.0523	0.0983	0.1243	0.1595	0.2098	0.1966	0.1300
68.3 °C	0.0311	0.0553	0.1029	0.1282	0.1617	0.2078	0.1900	0.1231
73.9 °C	0.0330	0.0584	0.1076	0.1322	0.1636	0.2055	0.1833	0.1165
79.4 °C	0.0351	0.0617	0.1125	0.1360	0.1653	0.2028	0.1766	0.1102

B	Enhanced							
Cooked Temperature[2]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
62.8 °C	0.0131	0.0245	0.0504	0.0733	0.1143	0.2002	0.2709	0.2534
68.3 °C	0.0127	0.0238	0.0491	0.0717	0.1124	0.1986	0.2726	0.2591
73.9 °C	0.0123	0.0232	0.0478	0.0700	0.1104	0.1970	0.2743	0.2649
79.4 °C	0.0120	0.0225	0.0466	0.0685	0.1085	0.1954	0.2758	0.2707

[1] To convert to a percent multiply probabilities by 100.
[2] Independent effect of cooked temperature with intramuscular fat, Minolta L*, ultimate pH, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

Across the cooked temperature range, approximately 35% of consumer rated non-enhanced chops 6 or greater for Flavor Like, increasing to approximately 63% of consumers rating enhanced chops as a 6, 7, or 8. These distributions further enforce the large positive impact that enhancement played in improving the consumer perceptions of eating quality characteristics.

These findings suggest two important conclusions for the swine industry: 1) Enhancement clearly improves eating quality at the consumer level and offers protection against the detrimental effects of increasing cooked temperature on eating quality, and 2) to optimize eating quality of non-enhanced pork chops relative to enhanced pork chops, suggested cooked temperature recommendations should reflect either 62.8 or 68.3° C end-point temperatures.

Table 8. **A:** Predicted probability[1] of consumer response for Flavor Like of non-enhanced chops cooked to four end-point temperatures. **B:** Predicted probability of consumer response for Flavor Like of enhanced chops cooked to four end-point temperatures.

A	Non-Enhanced							
Cooked Temperature[2]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
62.8 °C	0.0601	0.1075	0.1459	0.1502	0.1795	0.1660	0.1235	0.0673
68.3 °C	0.0602	0.1077	0.1460	0.1503	0.1795	0.1658	0.1233	0.0671
73.9 °C	0.0604	0.1078	0.1462	0.1504	0.1794	0.1657	0.1231	0.0670
79.4 °C	0.0605	0.1080	0.1464	0.1504	0.1794	0.1655	0.1229	0.0669

B	Enhanced							
Cooked Temperature[2]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
62.8 °C	0.0223	0.0447	0.0730	0.0956	0.1556	0.2107	0.2299	0.1683
68.3 °C	0.0209	0.0420	0.0692	0.0916	0.1516	0.2103	0.2365	0.1780
73.9 °C	0.0195	0.0395	0.0655	0.0876	0.1474	0.2096	0.2429	0.1880
79.4 °C	0.0183	0.0371	0.0619	0.0837	0.1431	0.2083	0.2490	0.1986

[1] To convert to a percent multiply probabilities by 100.
[2] Independent effect of cooked temperature with intramuscular fat, Minolta L*, ultimate pH, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

Consumer Sensory – Enhanced and Non-Enhanced Intramuscular Fat Effects

Predicted mean consumer ratings (Table 9) of Juiciness Like and Level attributes increased as IMF increased for both enhanced and non-enhanced chops. Consumer ratings increased a total of 0.23 units (2.8%) for non-enhanced chops and increased by 0.20 units (2.5%) for non-enhanced chops as IMF increased from 1% to 6%; however, while this increase was statistically significant, the incremental increase in consumer ratings with a 1% change in IMF were very small and of limited practical use at the industry level. Enhancement improved predicted mean consumer responses for Juiciness Like by approximately 0.9 units when compared with non-enhanced chops at an equal IMF level. The shift in the predicted mean response for the enhancement treatment improved the proportion of consumer ratings that were ≥ 6 by upwards of 22% when compared with a non-enhanced chop with equal IMF (Table 10). For enhanced chops, 74.6% and 78.8% of predicted consumer responses were ≥ 6 at 1 and 6% IMF, respectively. For non-enhanced chops, 51.5% and 57.3% of predicted consumer ratings were ≥ 6 at 1% and 6% IMF, respectively.

In the present study, IMF did not influence consumer perception of Tenderness Like which is in agreement with results presented by Rincker et al. (2008) who reported that IMF had little effect on tenderness (R^2 = 0.05 when cooked at 71° C). Van Laack et al. (2001) also reported that there was no significant relationship between IMF and tenderness scores. However, Brewer et al. (2001) reported that increasing IMF from <1% to 3.5% increased tenderness scores by 18.8%, and these findings were further supported by Fernandez et al. (1999), who indicated that increasing IMF levels above 2.25% had a beneficial impact on texture scores. Conflicting results continue to surface in the literature relative to the influence of IMF on perceptions of tenderness.

Increasing IMF resulted in a positive, beneficial increase in the predicted mean rating for both Flavor Level and Like across both enhanced and non-enhanced chops. Expected mean consumer responses increased across the IMF range by 0.34 units (4.25%) for non-enhanced chops and 0.30 units (3.75%) for enhanced chops suggesting that the tails of the IMF range evaluated in the present study were perceived to be different; however, an incremental, a one percentage unit increase in IMF would likely not result in a measurable change in a consumer's perception of pork flavor. Brewer et al. (2001) reported that as IMF increased from <1% to 3.5% flavor ratings increased 8%, larger impact than observed in the present study. Fernandez et al. (1999) reported that increasing IMF above 3.25% did not increase the linear benefits in detectable flavor of pork, but reported that IMF levels in pork need to reach a threshold value of 2% before there are any noticeable beneficial effects on flavor rating. Results of the present study do not indicate a threshold level of IMF in relation to flavor attributes, but do suggest that the influence of IMF on pork flavor attributes, while consistent across non-enhanced and enhanced chops, would have the greatest value when comparing or contrasting only very high with very low IMF levels. The influence of enhancement on the predicted distribution of consumer ratings Flavor Like at each level of IMF is presented in Table 11. Results reflect a greater proportion of favorable responses and a positive shift in the distribution of responses for enhanced pork when compared with non-enhanced pork across the range of IMF evaluated.

Table 9. Predicted[a] means for consumer assessment of pork eating quality measured on enhanced (E) and non-enhanced (N) pork loins measured across loin intramuscular fat levels.

	Intramuscular Fat, %											
	1		2		3		4		5		6	
Consumer Response[b]	Non	Enh	Non	Enh	Non	Enh	Non	Enh	Non	Enh	Non	Enh
Overall Like[x,y]	4.96	5.98	5.02	6.03	5.08	6.08	5.14	6.14	5.20	6.19	5.26	6.24
Juiciness Like[x,y]	5.32	6.27	5.37	6.31	5.41	6.35	5.46	6.39	5.51	6.43	5.55	6.47
Tenderness Like[x]	5.26	6.21	5.28	6.23	2.30	6.24	5.33	6.25	5.34	6.27	5.37	6.28
Flavor Like[x,y]	4.46	5.68	4.53	5.74	4.59	5.80	4.67	5.86	4.73	5.92	4.80	5.98
Juiciness Level[x]	5.32	6.30	5.34	6.31	5.36	6.33	5.37	6.34	5.39	6.36	5.41	6.37
Tenderness Level[x]	5.27	6.25	5.29	6.26	5.31	6.28	5.33	6.29	5.36	6.31	5.38	6.33
Flavor Level[x,y]	4.17	5.54	4.24	5.60	4.30	5.66	4.37	5.72	4.44	5.78	4.50	5.84
Likelihood of Purchase[c,xy]	2.99	3.70	3.03	3.73	3.06	3.76	3.09	3.79	3.12	3.81	3.15	3.84

[a] Independent effect of loin intramuscular fat with cooked temperature, Minolta L*, ultimate pH, and Warner-Bratzler Shear Force modeled effects adjusted to their respective mean value.
[b] Consumer responses assessed using and end-anchored 8-point Hedonic Scale; Like variables: 1 = Dislike Extremely, 8 = Like Extremely; Juiciness Level, 1 = Extremely Dry and 8 = Extremely Juicy; Tenderness Level, 1 = Extremely Tough and 8 = Extremely Tender; Flavor Level, 1 = No Flavor and 8 = Extremely Flavorful.
[c] Likelihood of Purchase: 1 = Definitely Would Not Buy, 3 = May or May not Buy, 5 = Definitely Would Buy.
[x] Main effect of Enhancement significant ($P < 0.01$)
[y] Main effect of Intramuscular Fat Percentage significant ($P < 0.05$).

Table 10. **A**: Predicted probability[1] of consumer response for Juiciness Like of non-enhanced chops across intramuscular fat (%). **B**: Predicted probability of consumer response for Juiciness Like of enhanced chops across intramuscular fat (%).

A	Non-Enhanced							
Intramuscular Fat (%)[2]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
1.0	0.0279	0.0526	0.0964	0.1296	0.1786	0.2251	0.1832	0.1066
2.0	0.0267	0.0505	0.0931	0.1264	0.1767	0.2270	0.1884	0.1112
3.0	0.0255	0.0484	0.0898	0.1232	0.1747	0.2288	0.1936	0.1160
4.0	0.0243	0.0463	0.0866	0.1200	0.1726	0.2303	0.1989	0.1209
5.0	0.0232	0.0444	0.0835	0.1168	0.1703	0.2316	0.2041	0.1260
6.0	0.0222	0.0425	0.0805	0.1136	0.1679	0.2327	0.2093	0.1313

B	Enhanced							
Intramuscular Fat (%)[2]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
1.0	0.0103	0.0204	0.0415	0.0657	0.1163	0.2157	0.2819	0.2481
2.0	0.0098	0.0195	0.0397	0.0633	0.1130	0.2128	0.2848	0.2570
3.0	0.0094	0.0187	0.0381	0.0609	0.1097	0.2098	0.2874	0.2661
4.0	0.0089	0.0178	0.0365	0.0587	0.1064	0.2066	0.2897	0.2754
5.0	0.0085	0.0170	0.0349	0.0564	0.1032	0.2032	0.2917	0.2849
6.0	0.0081	0.0163	0.0335	0.0543	0.1000	0.1997	0.2935	0.2946

[1] To convert to a percent multiply probabilities by 100.
[2] Independent effect of intramuscular fat with cooked temperature, Minolta L*, ultimate pH, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

Table 11: **A**: Predicted probability[1] of consumer response for Flavor Like of non-enhanced chops across intramuscular fat levels (%). **B**: Predicted probability of consumer response for Flavor Like of enhanced chops across intramuscular fat levels (%).

A	Non-Enhanced							
Intramuscular Fat (%)[2]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
1.0	0.0681	0.1189	0.1558	0.1541	0.1762	0.1557	0.1117	0.0593
2.0	0.0643	0.1136	0.1513	0.1525	0.1779	0.1605	0.1170	0.0629
3.0	0.0607	0.1083	0.1467	0.1506	0.1793	0.1652	0.1226	0.0666
4.0	0.0573	0.1033	0.1420	0.1484	0.1804	0.1698	0.1283	0.0705
5.0	0.0541	0.0984	0.1373	0.1461	0.1811	0.1742	0.1341	0.0747
6.0	0.0510	0.0937	0.1326	0.1435	0.1816	0.1785	0.1401	0.0791

B	Enhanced							
Intramuscular Fat (%)[2]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
1.0	0.0229	0.0459	0.0747	0.0973	0.1573	0.2107	0.2270	0.1643
2.0	0.0216	0.0434	0.0711	0.0937	0.1537	0.2106	0.2331	0.1729
3.0	0.0203	0.0410	0.0677	0.0900	0.1500	0.2101	0.2391	0.1819
4.0	0.0191	0.0387	0.0644	0.0864	0.1461	0.2092	0.2448	0.1912
5.0	0.0180	0.0366	0.0612	0.0829	0.1421	0.2080	0.2503	0.2009
6.0	0.0170	0.0345	0.0581	0.0794	0.1380	0.2064	0.2555	0.2110

[1] To convert to a percent multiply probabilities by 100.
[2] Independent effect of intramuscular fat with cooked temperature, Minolta L*, ultimate pH, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

Increasing IMF levels from a base of 1% to 6% had a small positive effect on the consumer's predicted mean rating of Overall Like for non-enhanced chops and enhanced chops, increasing the ratings by 0.3 units (3.75%) and 0.26 units (3.25%), respectively on the 8-point scale. Similar to the relationship described for the individual consumer attributes, the observed effect would likely be of most value when discriminating between the least and greatest IMF levels and would be of less importance when attempting to discriminate between slight changes in IMF. Enhancement improved Overall Like ratings by ~ 1.0 unit across the range of IMF assessed. The importance of enhancement on Overall Like of chops is most evident when assessing the distribution of consumer responses (Table 12). For chops at 1% IMF, 42.3% of consumers were predicted to rate non-enhanced chops as ≥ 6, whereas 67% of consumers were predicted to rate the enhanced chops as ≥ 6 on the 8-point scale. At 6% IMF, 49.5% of consumers were predicted to rate non-enhanced chops as ≥ 6, whereas 73% of consumers were predicted to the enhanced chops as ≥ 6 on the 8-point scale.

Table 12. **A**: Predicted probability[a] of consumer response for Overall Like of non-enhanced chops across intramuscular fat (%). **B**: Predicted probability[a] of consumer response for Overall Like of enhanced chops across intramuscular fat (%).

A	Non-Enhanced Chops							
Intramuscular Fat (%)[b]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
1.0	0.0420	0.0732	0.1216	0.1494	0.1901	0.1957	0.1416	0.0866
2.0	0.0397	0.0697	0.1170	0.1461	0.1896	0.1996	0.1472	0.0912
3.0	0.0375	0.0663	0.1126	0.1426	0.1887	0.2032	0.1529	0.0961
4.0	0.0355	0.0631	0.1082	0.1391	0.1875	0.2066	0.1588	0.1012
5.0	0.0336	0.0600	0.1039	0.1354	0.1861	0.2097	0.1647	0.1066
6.0	0.0318	0.0571	0.0997	0.1317	0.1843	0.2125	0.1706	0.1123

B	Enhanced Chops							
Intramuscular Fat (%)[b]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
1.0	0.0156	0.0294	0.0560	0.0846	0.1445	0.2208	0.2418	0.2071
2.0	0.0148	0.0279	0.0533	0.0812	0.1405	0.2191	0.2465	0.2167
3.0	0.0139	0.0264	0.0507	0.0778	0.1364	0.2172	0.2509	0.2267
4.0	0.0132	0.0250	0.0482	0.0745	0.1322	0.2148	0.2551	0.2370
5.0	0.0124	0.0237	0.0459	0.0713	0.1280	0.2122	0.2589	0.2476
6.0	0.0118	0.0224	0.0436	0.0683	0.1238	0.2092	0.2623	0.2586

[a] To convert to a percent multiply probabilities by 100.
[b] Independent effect of intramuscular fat with cooked temperature, Minolta L*, ultimate pH, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

The benefits of increasing the population mean IMF levels upward by 1% or even 2% in an effort to improve pork palatability attributes at the consumer level appear limited based on the data from the present study. Rather, IMF appears to provide value to consumer perceptions of eating quality at levels of 6% if or when comparisons are made with chops with approximately 1% IMF. Fortin et al. (2005) had proposed a 1.5% IMF lower limit and Devol et al. (1988) reported an IMF threshold between 2.5 and 3.0% IMF as requirements for ensuring an acceptable eating experience. Data from the present study do not support a threshold level for IMF or a major contribution of IMF to overall acceptability of eating quality, a finding that is supported by Rincker et al. (2008) who reported that intramuscular fat content had little influence on the eating quality of fresh pork loin chops.

Consumer Sensory – Enhanced and Non-Enhanced Loin pH Effects

Loin ultimate pH had a quadratic effect on all consumer attribute responses measured in the present study, whereby chops from a loin pH of 5.40 for both enhanced and non-enhanced samples, had reduced, less favorable ratings when compared with pH ratings across the range. Optimal loin pH levels varied across attributes, reflecting slightly different points of inflection across the pH range evaluated (Table 13).

Predicted mean responses for Juiciness Like and Level for non-enhanced and enhanced chops were greatest at a loin pH of approximately 6.00 with means of 5.49 and 6.41 units, respectively on the 8-point scale. The most pronounced negative impact of loin pH on consumer ratings of Juiciness Like and Level, across both enhanced and non-enhanced product, was observed for the 5.40 and 5.60 pH classes. The point of inflection for pH in relation to Juiciness Like and Level attributes was near 6.00 with values of 5.80 and 6.20 resulting in very similar consumer response ratings and a pH of 6.40 resulting in a slight decline in the predicted mean responses. This finding suggests

Table13. Predicted[a] means for consumer assessment of pork eating quality measured on enhanced (E) and non-enhanced (N) pork loins measured across loin ultimate pH levels.

	Loin pH											
	5.40		5.60		5.80		6.00		6.20		6.40	
Consumer Response[b]	N	E	N	E	N	E	N	E	N	E	N	E
Overall Like[x,y]	4.77	5.81	4.97	5.99	5.09	6.10	5.13	6.13	5.08	6.08	4.94	5.97
Juiciness Like[x,y]	5.06	6.26	5.28	6.24	5.43	6.36	5.49	6.41	5.46	6.39	5.36	6.30
Tenderness Like[x,y]	4.97	5.96	5.20	6.16	5.36	6.29	5.44	6.36	5.46	6.38	5.42	6.34
Flavor Like[x,y]	4.37	5.59	4.53	5.74	4.61	5.81	4.60	5.81	4.50	5.72	4.32	5.56
Juiciness Level[x,y]	4.91	5.94	5.19	6.18	5.37	6.34	5.47	6.42	5.47	6.42	5.39	6.36
Tenderness Level[x,y]	4.88	5.90	5.13	6.13	5.32	6.29	5.45	6.38	5.51	6.45	5.51	6.45
Flavor Level[x,y]	4.18	5.53	4.28	5.63	4.31	5.66	4.28	5.64	4.20	5.56	4.06	5.44
Likelihood of Purchase[c,x,y]	2.88	3.59	2.99	3.70	3.06	3.76	3.09	3.79	3.08	3.78	3.02	3.73

[a] Independent effect of loin ultimate pH with cooked temperature, intramuscular fat, Minolta L*, ultimate pH, and Warner-Bratzler Shear Force modeled effects adjusted to their respective mean value.
[b] Consumer responses assessed using and end-anchored 8-point Hedonic Scale; Like variables: 1 = Dislike Extremely, 8 = Like Extremely; Juiciness Level, 1 = Extremely Dry and 8 = Extremely Juicy; Tenderness Level, 1 = Extremely Tough and 8 = Extremely Tender; Flavor Level, 1 = No Flavor and 8 = Extremely Flavorful.
[c] Likelihood of Purchase: 1 = Definitely Would Not Buy, 3 = May or May not Buy, 5 = Definitely Would Buy.
[x] Main effect of Enhancement significant ($P < 0.01$)
[y] Main effects of loin ultimate pH and quadratic loin pH significant ($P < 0.03$).

that low ultimate pH plays a large role in reducing loin juiciness, likely due to the lower inherent water holding capacity capabilities of the loin, regardless of enhancement. Enhancement, as a primary effect, improved predicted consumer ratings across the pH range studied with the effect being an approximate 0.90 unit (11.3%) increase when compared with corresponding non-enhanced predicted means. Lonergan et al. (2007) had reported an 8% increase in juiciness rating as pH increased from <5.5 to >5.95, which is slightly greater than the 5.38% improvement observed when comparing a pH of 5.40 with a pH of 6.00 in the present study. Increasing pH from 5.40 to 6.00 for non-enhanced chops resulted in a ~ 10% (45.2% vs. 55.6%) improvement in the predicted proportion of consumer ratings (Table 14) for Juiciness Like as 6 or greater, whereas 69.5% and 77.6% of consumers were predicted to rate Juiciness Like chops as ≥ 6 at a loin pH of 5.40 and 6.00, respectively.

Loin pH influenced consumer perception of Tenderness Like and Level, with predicted mean consumer responses being most favorable at a pH of ~ 6.20 (5.47 units and 6.38 units on an 8-point scale for non-enhanced and enhanced loins, respectively). Enhancement treatment had a positive, additive effect of approximately 0.90 units (11.3%) when loin pH was near 6.2, with a slightly larger effect (~ 1.0 unit) when loin pH was 5.40. Predicted probabilities of consumer responses for Tenderness Like (Table 15) indicate the lowest proportion of favorable responses (≥ 6) were observed at a loin pH of 5.40 for non-enhanced (46.3%) and enhanced (66.8%) chops, with the predicted proportion of ratings increasing to 55.2% (non-enhanced) and 76.3% (enhanced) when fresh loin pH was increased to 6.20. Lonergan et al. (2007) reported a somewhat similar relationships between loin pH and trained sensory evaluations of tenderness, whereby for non-enhanced chops, as loin pH increased from a classification of < 5.5 pH was compared with a pH classification of > 5.95, tenderness ratings improved 10%. High pH products are thought to be more tender as a result of a faster rate of rigor mortis which results in a more rapid completion of the rigor phase, thus allowing more time for post-rigor proteolytic degradation to occur (Gardner et al., 2005). Huff-Lonergan et al. (2002) reported a moderate relationship (r = 0.27) relationship between loin pH and tenderness rating, while in contrast Davis et al. (1975) and Devol et al. (1988) reported no significant correlation between loin pH and tenderness. In the present study, loin pH had a positive but weak relationship with Tenderness Like for non-enhanced chops (r = 0.16) and there was essentially no relationship (r = 0.03) between loin pH and Tenderness Like when evaluated within the enhanced loin subset. The lack of strong linear associations between loin pH and tenderness-related attributes provide a challenge with respect to interpretation of the causal effect of pH on tenderness assessments at the consumer level.

Table 14. **A**: Predicted probability[a] of consumer response for Juiciness Like of non-enhanced chops across ultimate pH values. **B**: Predicted probability[a] of consumer response for Juiciness Like of enhanced chops across ultimate pH values.

A	Non-Enhanced							
Ultimate pH[b]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
5.4	0.0356	0.0657	0.1154	0.1458	0.1854	0.2112	0.1559	0.0849
5.6	0.0288	0.0541	0.0986	0.1316	0.1797	0.2237	0.1798	0.1037
5.8	0.0251	0.0478	0.0889	0.1223	0.1741	0.2293	0.1952	0.1174
6.0	0.0237	0.0453	0.0850	0.1184	0.1714	0.2310	0.2016	0.1235
6.2	0.0243	0.0463	0.0866	0.1200	0.1726	0.2303	0.1989	0.1209
6.4	0.0270	0.0510	0.0939	0.1272	0.1772	0.2266	0.1871	0.1101

B	Enhanced							
Ultimate pH[b]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
5.4	0.0132	0.0260	0.0518	0.0797	0.1342	0.2280	0.2630	0.2041
5.6	0.0106	0.0211	0.0426	0.0673	0.1185	0.2175	0.2800	0.2424
5.8	0.0092	0.0184	0.0376	0.0602	0.1087	0.2088	0.2881	0.2689
6.0	0.0087	0.0174	0.0357	0.0575	0.1048	0.2049	0.2908	0.2803
6.2	0.0089	0.0178	0.0365	0.0586	0.1064	0.2066	0.2897	0.2754
6.4	0.0099	0.0198	0.0402	0.0639	0.1138	0.2136	0.2841	0.2548

[a] To convert to a percent multiply probabilities by 100.
[b] Independent effect of ultimate pH with intramuscular fat, Minolta L*, cooked temperature, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

Predicted means for consumer perceptions of Flavor Like and Level were the greatest for enhanced (5.81) and non-enhanced (4.61) chops at a loin pH of 5.80 with similar responses at a pH classification of 6.00. The ends of the pH ranged evaluated (5.40 and 6.40) had similar predicted mean ratings and represented the lowest predicted consumer response means for both enhanced and non-enhanced loins. Enhancement treatment had a positive impact on Flavor Like and Level, improving predicted mean responses by approximately 1.22 and 1.35 units respectively at each level of loin pH.

Table 15. **A**: Predicted probability[a] of consumer response for Tenderness Like of non-enhanced chops across ultimate pH values. **B**: Predicted probability[a] of consumer response for Tenderness Like of enhanced chops across ultimate pH values.

A	Non-Enhanced							
Ultimate pH[b]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
5.4	0.0432	0.0742	0.1299	0.1484	0.1686	0.1912	0.1539	0.0907
5.6	0.0351	0.0618	0.1126	0.1361	0.1653	0.2027	0.1764	0.1100
5.8	0.0304	0.0542	0.1012	0.1268	0.1609	0.2085	0.1924	0.1255
6.0	0.0280	0.0502	0.0951	0.1214	0.1578	0.2110	0.2014	0.1351
6.2	0.0275	0.0494	0.0937	0.1201	0.1570	0.2114	0.2035	0.1375
6.4	0.0287	0.0514	0.0969	0.1230	0.1588	0.2103	0.1988	0.1322

B	Enhanced							
Ultimate pH[b]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
5.4	0.0170	0.0315	0.0633	0.0887	0.1311	0.2104	0.2515	0.2065
5.6	0.0138	0.0257	0.0527	0.0761	0.1176	0.2026	0.2677	0.2439
5.8	0.0119	0.0223	0.0462	0.0680	0.1079	0.1949	0.2763	0.2725
6.0	0.0109	0.0206	0.0429	0.0636	0.1025	0.1898	0.2800	0.2896
6.2	0.0107	0.0202	0.0421	0.0626	0.1012	0.1886	0.2808	0.2937
6.4	0.0112	0.0211	0.0438	0.0649	0.1041	0.1914	0.2790	0.2845

[a] To convert to a percent multiply probabilities by 100.
[b] Independent effect of ultimate pH with intramuscular fat, Minolta L*, cooked temperature, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

Following a similar quadratic response pattern, predicted mean consumer responses for Overall Like were optimized for a loin pH between 5.80 and 6.20 with lower predicted mean responses at pH level of 5.40, 5.60 and 6.40. Changing pH from 5.40 to 6.00 increased the predicted mean responses by 0.32 units (4%) and 0.36 units (4.5%) for enhanced and non-enhanced chops respectively, indicating a consistent response across the enhanced and non-enhanced treatments. Enhancement alone increased predicted mean responses by 1.0 unit at each pH level and shifted the proportion of favorable responses sharply toward the upper end of the response surface (Figure 1), supporting the contribution of enhancement to the specific descriptive attributes previously discussed.

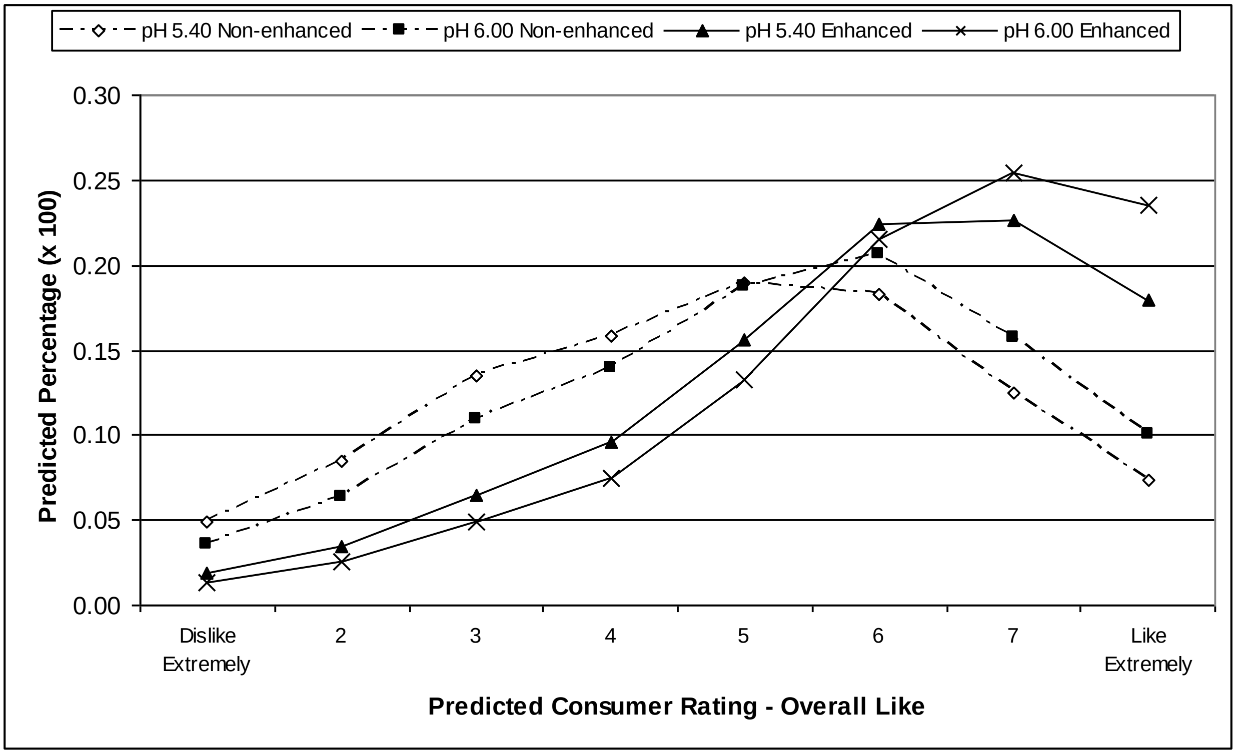


Figure 1. Predicted percentage of consumer responses graphed across response surface for loin pH measurements representing the minimum (ph = 5.40) and optimal (pH = 6.00) pH for the consumer assessment of Overall Like of enhanced and non-enhanced loin chops.

Warner Bratzler Shear Force Effects

Increasing Warner-Bratzler shear force in both enhanced and non-enhanced chops reduced predicted mean responses for each consumer descriptive attribute evaluated in the present study and the effect of WBS represented the largest overall impact on consumer response criteria of the fresh pork quality indicator trait evaluated. As described previously in Table 1, enhancement of the loins reduced arithmetic mean WBS of chops by 0.70 kg to 1.05 kg when comparing the ends of the temperature range assessed, and the increase in cooked temperature had little impact on chops from loins that were enhanced. The result was a smaller range and a reduction in the maximum level of WBS evaluated within the enhanced chop data set. Results of logistical regression analyses were projected to reflect the range of WBS observed in the non-enhanced subset of data, and therefore reflect an extension of the regression line for enhanced product to reflect non-enhanced WBS variation.

Predicted mean consumer responses for Juiciness Like (Figure 2) indicate a reduction in consumer ratings of approximately 0.20 units for each 0.50 kg incremental increase in WBS for both enhanced and non-enhanced chops, indicating that perception of juiciness, while not a direct measure of tenderness, is influenced by the level of tenderness/toughness. Across the range evaluated the most tender WBS category (1.5 kg) was rated 1.78 and 1.61 units greater than the toughest WBS category (6.0 kg) for non-enhanced and enhanced chops, respectively. In addition, enhancement improved Juiciness Like ratings by approximately 1 unit on the 8 unit scale. The correlation between WBS and Juiciness Like rating in the present study was $r = -0.19$ and $r = -0.09$ for non-enhanced and enhanced chops, respectively, which were generally small. Hodgson et al. (1991) also reported a significant but somewhat stronger ($r = -0.39$) relationship between WBS and consumer juiciness ratings. Based on the predicted mean responses reported, non-enhanced chops needed to have a WBS value of ≤ 3.0 kg to have an expected mean response that is considered on the favorable side (5 or greater) of the 8-point scale; while in contrast; enhanced chops would need have a WBS value of ≤ 5.5 kg to have a predicted mean Juiciness Like response that was ≥ 5 and considered acceptable for consumer preference.

The relationships between WBS, a mechanical assessment used to estimate a consumer's perception of tenderness, and a direct assessment of Tenderness Like by the consumer (Figure 3 indicated a negative association between the traits for non-enhanced (r = -0.22) and a weak, negative association for enhanced chops (r = -0.11). Caine et al. (2003) had previously reported a very large, negative (r = -0.72) relationship between WBS and perceived tenderness, a value much greater than observed in the present study. For non-enhanced chops, a 2.53 unit (31.6%) reduction in ratings on the 8-point scale was observed when comparing tender (1.5 kg) to very tough (6.0 kg) pork. For enhanced chops, predicted mean responses declined by 2.41 units (30.1%) when comparing 1.5 and 6.0 kg WBS levels indicating a similar rate of decline as the non-enhanced chops; however, the chops from enhanced loins had 1.0 unit greater predicted Tenderness Like mean rating at each point across the range of WBS studied. With a response level of five representing the first full unit on the favorable side of the response scale, the enhancement treatment allowed chops to reach a WBS level of up to 4.0 kg before the predicted mean responses declined to less than five on the scale.

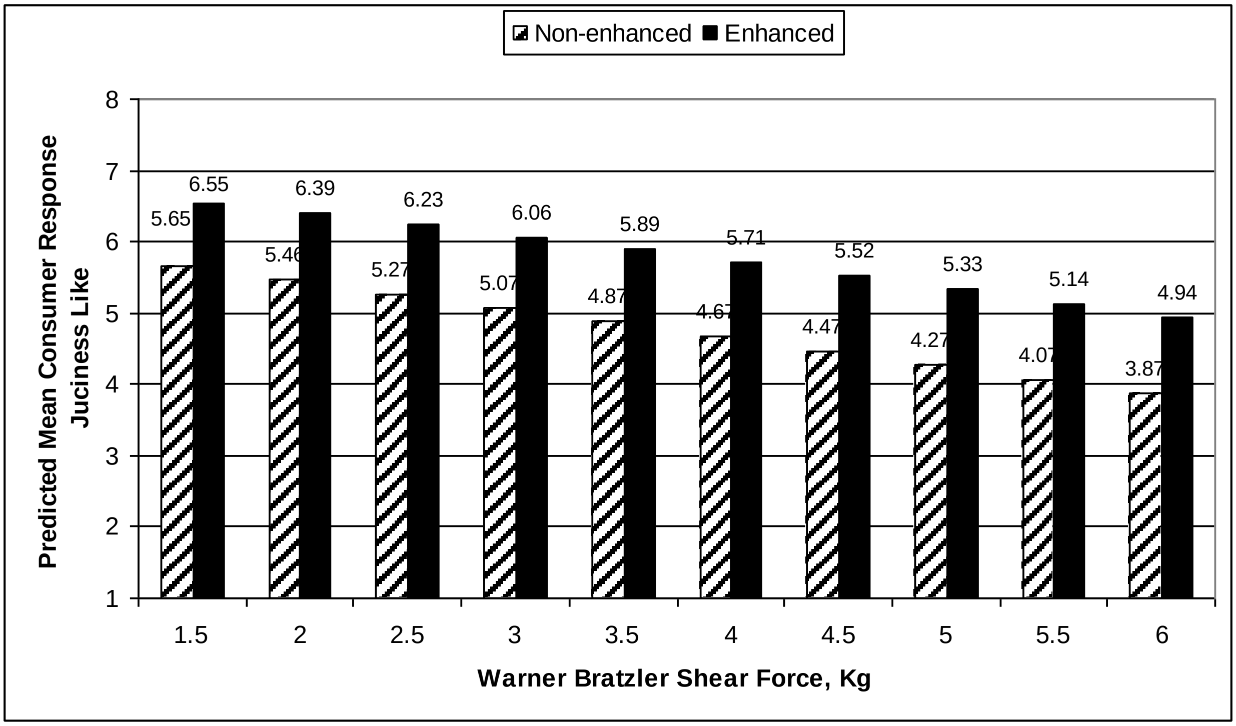


Figure 2. Predicted mean consumer responses for Juiciness Like of non-enhanced and enhanced chops across Warner Bratzler Shear Force values.

In contrast, chops from non-enhanced loins had to have WBS levels of ≤ 2.5 kg to maintain a predicted mean response that was greater than five. In the present study, differences in unadjusted mean WBS values were approximately 0.70 to 1.05 kg which is in agreement with the observed positive influence of enhancement on perception of Tenderness Like. However, the shift in the predicted mean and associated shift in the distribution of consumer response ratings for enhanced chops across the WBS range suggests that enhancement created a positive perception of tenderness that went beyond the effect of WBS alone. Sheard et al. (1999) had reported that enhanced chops were 10.5% more tender than non-enhanced chops. It is thought that the inclusion of phosphates can increase tenderness by weakening the binding of myosin heads to actin and promotes the dissociation of actomyosin cross-bridges (Offer and Trinick, 1983).

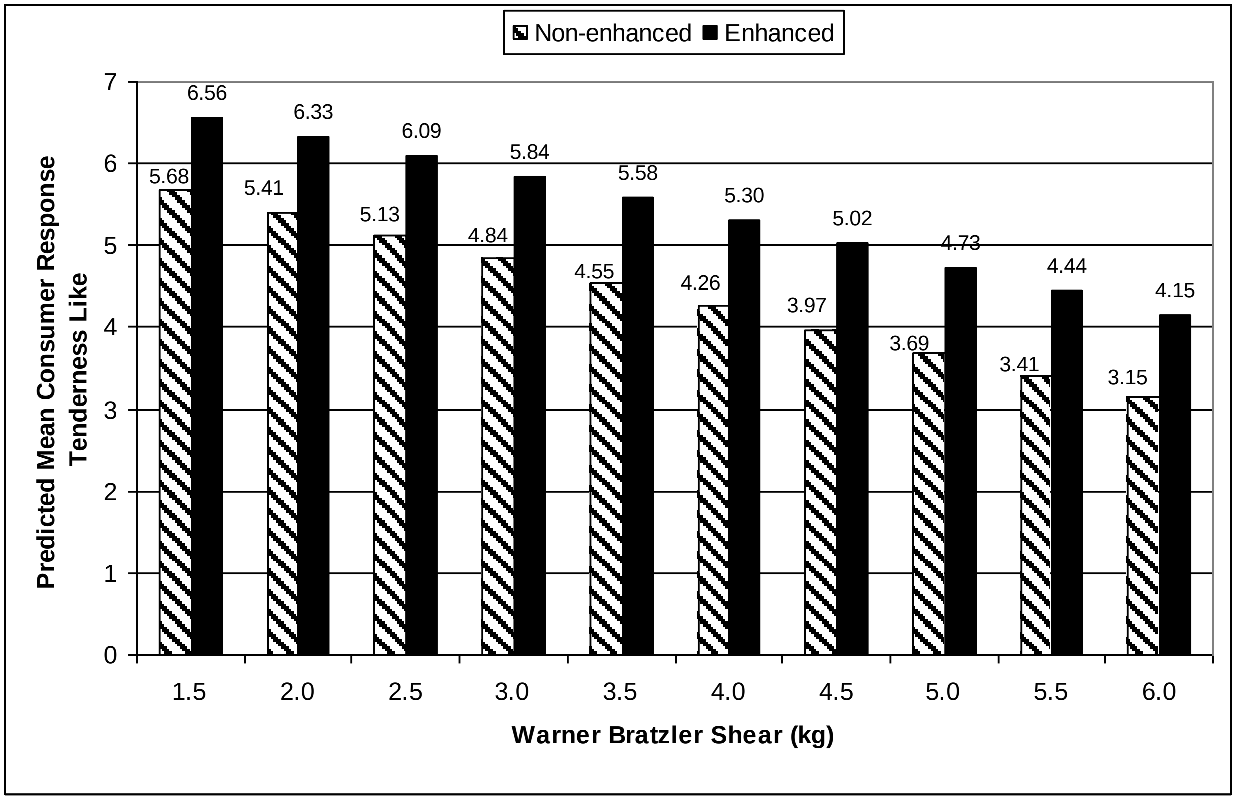


Figure 3. Predicted mean consumer responses for Tenderness Like of non-enhanced and enhanced chops across Warner Bratzler Shear Force values.

The distribution of consumer ratings for Tenderness Like (Figure 4) indicate that 60.3% of consumers were expected to rate non-enhanced chops as ≥ 6 at the most tender category (1.5 kg) and the predicted proportion declined by ~ 4.8% for each 0.5 kg increase in WBS resulting in only 12.3% of consumers predicted to rate chops as ≥ 6 when WBS of non-enhanced chops increased to 6.0 kg. Enhancement improved the predicted proportion Tenderness Like ratings that were greater than 6, with 79.9% of consumer predicted to rate chops as ≥ 6 at a WBS of 1.5 kg, decreasing to 26.6% if WBS increased to 6.0 kg.

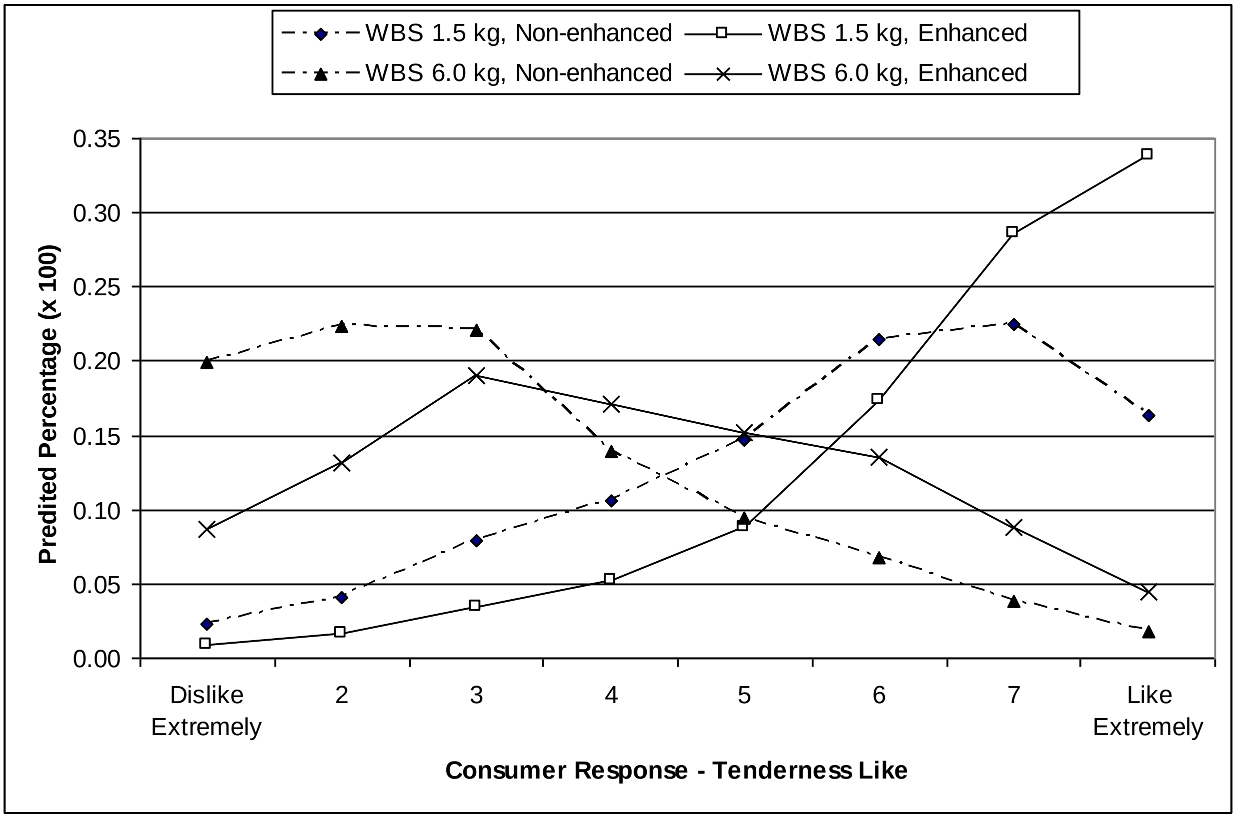


Figure 4. Predicted percentage of consumer responses within each category of the response surface for Tenderness Like of non-enhanced and enhanced chops at the lowest (1.5 kg) and greatest (6.0 kg) Warner Bratzler Shear Force values.

Increasing WBS in non-enhanced and enhanced chops resulted in 0.97 and 0.91 unit reductions in predicted mean responses for Flavor Like, respectively, when comparing 1.5 and 6.0 kg shear levels (Figure 5). These results support the moderate to large correlation coefficients (r = 0.52 to 0.63) observed between the consumer responses associated with Tenderness Like and Level in relation to Flavor Like and

Level in both enhanced and non-enhanced product served in the present study. Increasing WBS from 1.5 to 6.0 kg reduced the predicted percentage of consumer responses that were greater than 6 for Flavor Like from 38.4% to 20.6% for non-enhanced chops and decreased the predicted percentage from 66.0% to 44.6% in enhanced pork.

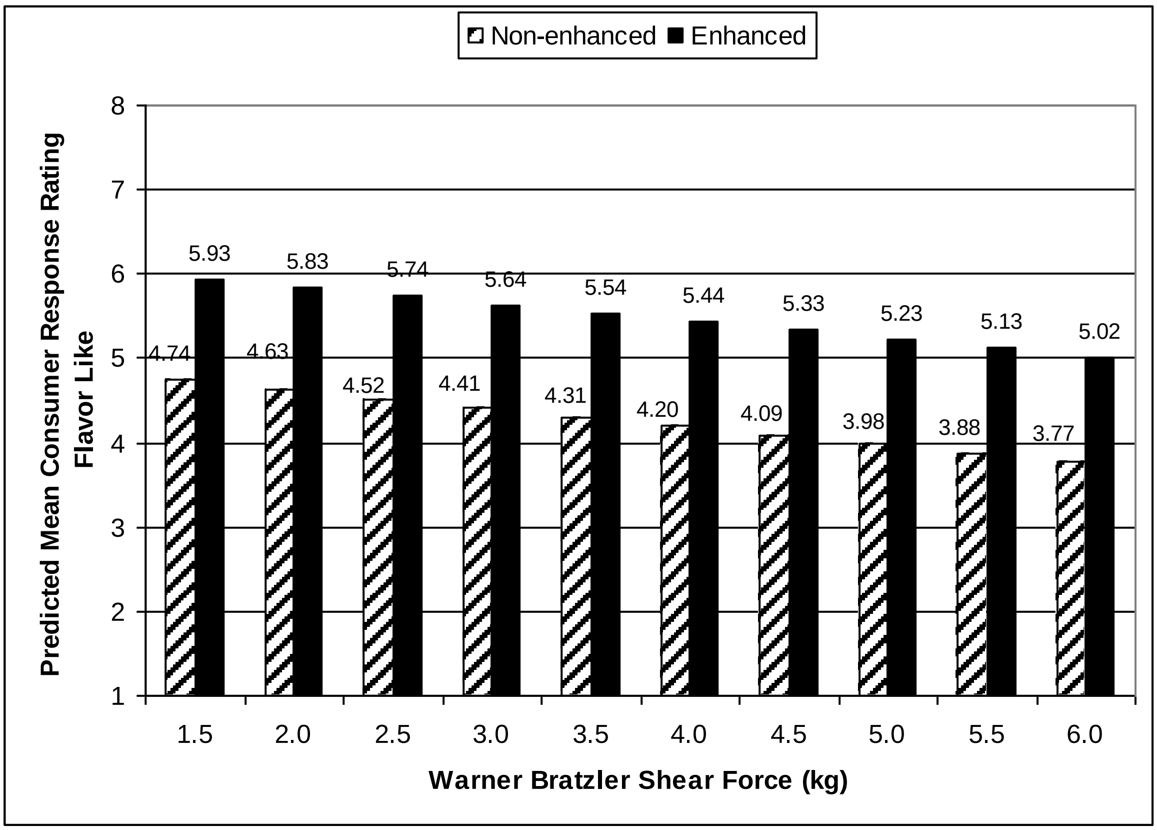
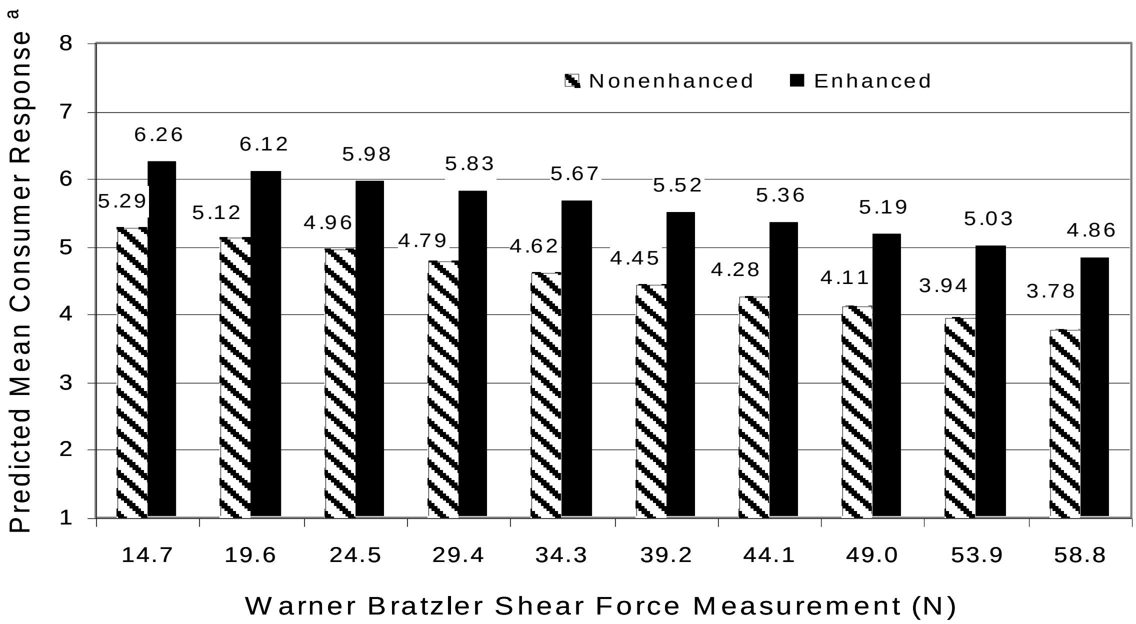


Figure 5. Predicted mean consumer responses for Flavor Like of non-enhanced and enhanced chops across Warner Bratzler Shear Force values.

Increasing WBS from 1.5 to 6.0 kg reduced the predicted mean consumer responses for Overall Like (Figure 6) for non-enhanced chops 1.51 units (18.9%) and 1.4 units (17.5%) for enhanced chops, indicating a culmination of results previously described for juiciness, tenderness, and flavor related descriptive attributes.

Incremental increases in WBS of 0.5 kg resulted in approximately a 0.16 unit decline in the predicted mean response over the WBS range studied in both enhanced and non-enhanced chops. When assessed each level of WBS, the enhanced chops were rated on average 1.0 unit greater, representing similar, favorable responses observed previously for juiciness, tenderness and flavor responses. When assessing Overall Like at the average WBS of non-enhanced chops (~ 2.5 kg) the predicted mean response for Overall Like was near 4.96 while at the mean WBS of enhanced chops (~ 1.6 kg) the enhanced chops were rated near 6.20. Similar to previous discussions regarding WBS, enhancement created a shift in the acceptable level of WBS as it relates to the consumer's rating for Overall Like. To achieve a predicted mean response of 5 on the 8-point scale, non-enhanced chops needed to have a WBS value of ≤ 2.5 kg while enhanced chops would receive an predicted mean rating of five or greater with a WBS value of 5.5 kg or less.



[a] Consumer Response, end anchored 8-point Hedonic Scale; 1 = extremely dislike, 8 = extremely like

Figure 6: Predicted mean consumer responses for Overall Like of non-enhanced and enhanced chops across Warner Bratzler Shear Force values.

Analysis of the predicted probability distribution (Table 15) for consumer ratings assessed across shear force levels provides evidence of the pronounced impact enhancement of pork loins had on consumer perception of Overall Like. Greater than 52% of consumer responses were predicted to be rated as a 7 or 8 for enhanced chops at 1.5 kg WBS, whereas for non-enhanced chops at 1.5 kg WBS only 28% of responses were predicted to be a 7 or 8 rating. At a WBS of 6.0 kg, 21.3% of consumers were expected to rate enhanced product as a 7 or 8, while the predicted proportion was reduced to 8.8% in the non-enhanced chops at a 6.0 kg WBS level. The dramatic upward shift in the proportions of consumer responses that represented the most favorable ratings emphasizes the strong positive influence that enhancement had on consumer perceptions across WBS range and also identifies the disadvantage in consumer ratings for non-enhanced chops even at relatively small WBS levels.

Consumer response for Overall Like was significantly affected by several independent variables including IMF, cooked temperature, and pH; however, enhancement treatment and WBS values represent the largest effects on consumer perceptions of Overall Like. Consumers are able to detect differences in level of tenderness and have shown that they prefer chops that are tender. Consumers are able to detect differences in WBS of about 1.0 kg N if tasting occurs in a restaurant and approximately 0.5 kg if tasting occurs in the home (Miller et al. 1995). In the present study, WBS was significantly correlated to Overall Like/Dislike (r = -0.29). Hodgson et al. (1991) presented similar findings in WBS and overall palatability rating are moderately correlated (r = -0.51) and that the greatest overall palatability ratings were associated with non-enhanced chops with low WBS values. Enhancement treatment across all variables has an additive effect of approximately 1 unit (~12.5%) increase across all independent variable ranges.

Table 15: **A**: Predicted probability[a] of consumer response for Overall Like of non-enhanced chops across Warner Bratzler Shear Force Values (kg). **B**: Predicted probability[a] of consumer response for Overall Like of enhanced chops across Warner Bratzler Shear Force Values (kg).

A	Non-Enhanced							
WBS (kg)[b]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
1.5	0.0310	0.0557	0.0978	0.1300	0.1834	0.2138	0.1734	0.1150
2.0	0.0361	0.0640	0.1094	0.1401	0.1879	0.2057	0.1572	0.0998
2.5	0.0420	0.0732	0.1216	0.1494	0.1902	0.1957	0.1415	0.0864
3.0	0.0488	0.0835	0.1342	0.1578	0.1901	0.1842	0.1265	0.0747
3.5	0.0567	0.0949	0.1470	0.1647	0.1878	0.1717	0.1125	0.0645
4.0	0.0658	0.1073	0.1597	0.1700	0.1833	0.1586	0.0996	0.0557
4.5	0.0763	0.1208	0.1718	0.1733	0.1768	0.1452	0.0878	0.0480
5.0	0.0883	0.1351	0.1830	0.1746	0.1686	0.1320	0.0771	0.0413
5.5	0.1021	0.1501	0.1929	0.1738	0.1591	0.1191	0.0675	0.0355
6.0	0.1176	0.1657	0.2010	0.1708	0.1487	0.1068	0.0589	0.0305
B	Enhanced							
WBS (kg)[b]	Dislike Extremely (1)	2	3	4	5	6	7	Like Extremely (8)
1.5	0.0114	0.0218	0.0425	0.0668	0.1219	0.2079	0.2640	0.2636
2.0	0.0134	0.0254	0.0489	0.0754	0.1333	0.2155	0.2540	0.2341
2.5	0.0156	0.0295	0.0561	0.0847	0.1446	0.2208	0.2417	0.2070
3.0	0.0183	0.0342	0.0641	0.0945	0.1553	0.2236	0.2277	0.1823
3.5	0.0214	0.0396	0.0730	0.1048	0.1652	0.2237	0.2125	0.1600
4.0	0.0250	0.0458	0.0828	0.1152	0.1737	0.2211	0.1964	0.1400
4.5	0.0292	0.0528	0.0934	0.1257	0.1807	0.2161	0.1801	0.1221
5.0	0.0341	0.0608	0.1047	0.1358	0.1857	0.2087	0.1639	0.1063
5.5	0.0398	0.0697	0.1167	0.1453	0.1886	0.1994	0.1481	0.0924
6.0	0.0464	0.0797	0.1292	0.1539	0.1893	0.1885	0.1330	0.0802

[a] To convert to a percent multiply probabilities by 100.
[b] Independent effect of Warner Bratzler shear force with intramuscular fat, Minolta L*, ultimate pH, and cooked temperature modeled effects adjusted to their respective mean value.

Color Effects

Minolta L* color was not a significant contributor to variation in the consumer descriptive attributes evaluated in the present study when evaluated in the presence of model effects including loin pH and WBS. The authors hypothesize that the relatively strong correlation between Minolta L* (r = - 0.70 for enhanced chops and r = - 0.62 for non-enhanced chops) may have allowed loin pH to account for or absorb the correlated loin color effects. Previous research (Anderson et al., 1975 and Norman et al., 2003) has also reported that no relationship exists between darkness of color and level of tenderness in pork loins which is in agreement with findings in the present study.

Likelihood of Purchase

Likelihood of purchase responses, an attempt in the present study to summarize the culmination of the eating experience for each chop served, were very neutral, with means very near 3.0 across each of the independent traits evaluated for the non-enhanced product. Enhancement improved mean responses for independent variables by as much as 0.83 units to mean levels near 3.8 when evaluating a specific independent variable effect. The lower mean responses for non-enhanced pork clearly represents the results previously presented in the manuscript and are indicative of the beneficial influences that enhancement had on consumer ratings across the pork quality attributes evaluated in the present study.

Similar to consumer palatability attribute assessments, increasing cooked temperature reduced mean consumer responses for likelihood of purchase for non-enhanced chops (-0.14 unit, -2.8% change) and improved the mean consumer response for enhanced chops (+0.11 unit, +2.2%) indicative of the enhancement × cooked temperature interaction and supporting the detrimental impact of increasing cooked temperature on non-enhanced pork chops (Table 8). The difference in purchase intent when comparing enhanced with non-enhanced chops increased from 0.58 units at 62.8º C to 0.83 units at a cooked temperature of 79.4º C. This finding may support a need for differential cooked temperature recommendations for enhanced chops when compared with non-enhanced loins. The distribution of consumer responses (Table 16) indicates a peak in the percentage of predicted responses at a level of 3 (May or May Not Purchase) across cooked temperatures and a decline in the proportion of responses at 4 (Probably Would Purchase) and 5 (Definitely Would Purchase) when assessing non-enhanced chops. In contrast, enhanced chops had greater proportions of predicted responses of 4 and 5 when compared with non-enhanced chops at all cooked temperatures.

Table 16: **A:** Predicted probability[1] of consumer response for Likelihood of Purchase of non-enhanced chops cooked to four end-point temperatures. **B:** Predicted probability of consumer response for Likelihood of Purchase of enhanced chops cooked to four end-point temperatures.

A	Non-Enhanced				
Cooked Temperature[2]	Definitely Would Not Purchase (1)	Probably Would Not Purchase (2)	May or May not Purchase (3)	Probably Would Purchase (4)	Definitely Would Purchase (5)
62.8 °C	0.1117	0.2066	0.2709	0.2609	0.1498
68.3 °C	0.1187	0.2147	0.2724	0.2530	0.1413
73.9 °C	0.1260	0.2227	0.2732	0.2448	0.1332
79.4 °C	0.1338	0.2307	0.2734	0.2366	0.1255

B	Enhanced				
Cooked Temperature[2]	Definitely Would Not Purchase (1)	Probably Would Not Purchase (2)	May or May not Purchase (3)	Probably Would Purchase (4)	Definitely Would Purchase (5)
62.8 °C	0.0499	0.1134	0.2116	0.3286	0.2964
68.3 °C	0.0472	0.1082	0.2058	0.3298	0.3089
73.9 °C	0.0446	0.1032	0.1998	0.3306	0.3218
79.4 °C	0.0422	0.0983	0.1938	0.3309	0.3349

[1] To convert to a percent multiply probabilities by 100.
[2] Independent effect of cooked temperature with intramuscular fat, Minolta L*, ultimate pH, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

Predicted mean response for Likelihood of Purchase (Table 9) increased significantly as IMF increased from 1% to 6%, with the response increasing by 0.16 units (3.2%) for non-enhanced chops and 0.14 units for enhanced chops. However, the influence of increases of loin IMF in 1% increments was very small and not of a magnitude to have a meaningful impact at the commercial production level.

Loin pH influenced Likelihood of Purchase in a quadratic manner, with much lower predicted mean responses when pH was near 5.40 to 5.60 and a greater predicted mean responses with a plateau effect as pH approached 5.80 to 6.20 (Table 13). Only 39.8% of consumers were predicted to rate likelihood of purchase as a 4 (Probably Would Buy) or 5 (Definitely Would Buy) for non-enhanced chops at the optimal pH of ~ 6.00 while enhancement increased the percentage of 4 and 5 ratings to 65.7% at the same pH (Table 17).

Increasing WBS resulted in a reduction in the predicted mean consumer responses for Likelihood of Purchase (Figure 7) by 0.84 and 0.82 units for non-enhanced and enhanced chops, respectively, when comparing WBS at 1.5 and 6.0 kg levels. Enhancement improved the predicted mean rating for Likelihood of Purchase by ~ 0.70 units across the WBS range. Of note, the predicted mean response for non-enhanced chops was less than three on the 5-point scale for a relatively tender (2.5 kg WBS) chop whereas enhancement allowed predicted mean responses to remain greater than three up to a projected 6.0 kg WBS level. Predicted probabilities of consumer responses for Likelihood of Purchase at individual WBS levels are presented in Table 18. Enhancement improved the predicted proportion of consumers rating chops as a 4 (probably would buy) and 5 (definitely would buy) at a 1.5 kg WBS level by 25.6% (68.3 vs. 42.7%) when compared with non-enhanced chop ratings at a 1.5 kg

WBS level. Projecting the impact of enhancement to the toughest category of pork consumed (6.0 kg), 38.2% of consumers were predicted to rate the enhanced pork as a 4 or 5 on the scale, a value which was only 4.5% lower than the greatest predicted proportion of consumer responses for non-enhanced chops at a 1.5 kg WBS level.

Table 17: **A**: Predicted probability[1] of consumer response for Likelihood of Purchase of non-enhanced chops across ultimate pH values. **B:** Predicted probability of consumer response for Likelihood of Purchase of enhanced chops across ultimate pH values.

A	Non-Enhanced				
Ultimate pH[2]	Definitely Would Not Purchase (1)	Probably Would Not Purchase (2)	May or May not Purchase (3)	Probably Would Purchase (4)	Definitely Would Purchase (5)
5.4	0.1539	0.2493	0.2716	0.2166	0.1086
5.6	0.1333	0.2302	0.2735	0.2371	0.1259
5.8	0.1216	0.2179	0.2728	0.2497	0.1380
6.0	0.1171	0.2129	0.2721	0.2547	0.1431
6.2	0.1192	0.2153	0.2724	0.2524	0.1407
6.4	0.1282	0.2250	0.2733	0.2426	0.1310

B	Enhanced				
Ultimate pH[2]	Definitely Would Not Purchase (1)	Probably Would Not Purchase (2)	May or May not Purchase (3)	Probably Would Purchase (4)	Definitely Would Purchase (5)
5.4	0.0591	0.1300	0.2283	0.3218	0.2608
5.6	0.0504	0.1143	0.2125	0.3283	0.2944
5.8	0.0456	0.1051	0.2021	0.3304	0.3168
6.0	0.0438	0.1016	0.1978	0.3308	0.3261
6.2	0.0446	0.1032	0.1998	0.3306	0.3217
6.4	0.0483	0.1103	0.2081	0.3294	0.3039

[1] To convert to a percent multiply probabilities by 100.

[2] Independent effect of ultimate pH with intramuscular fat, Minolta L*, cooked temperature, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

Likelihood of Purchase responses were also highly and favorably associated with Overall Like (r = 0.81), Flavor Like (r = 0.80), Tenderness Like (r = 0.71), and Juiciness like (r = 0.69) as would be expected, indicating strong associations between consumer perceptions of eating quality attributes and purchase attitude. In contrast, correlations between Likelihood of Purchase and the independent variables used by the industry as potential indicators of purchase intent were low, indicating current pork quality measures may not adequately describe or account for a variation in consumer Likelihood of Purchase.

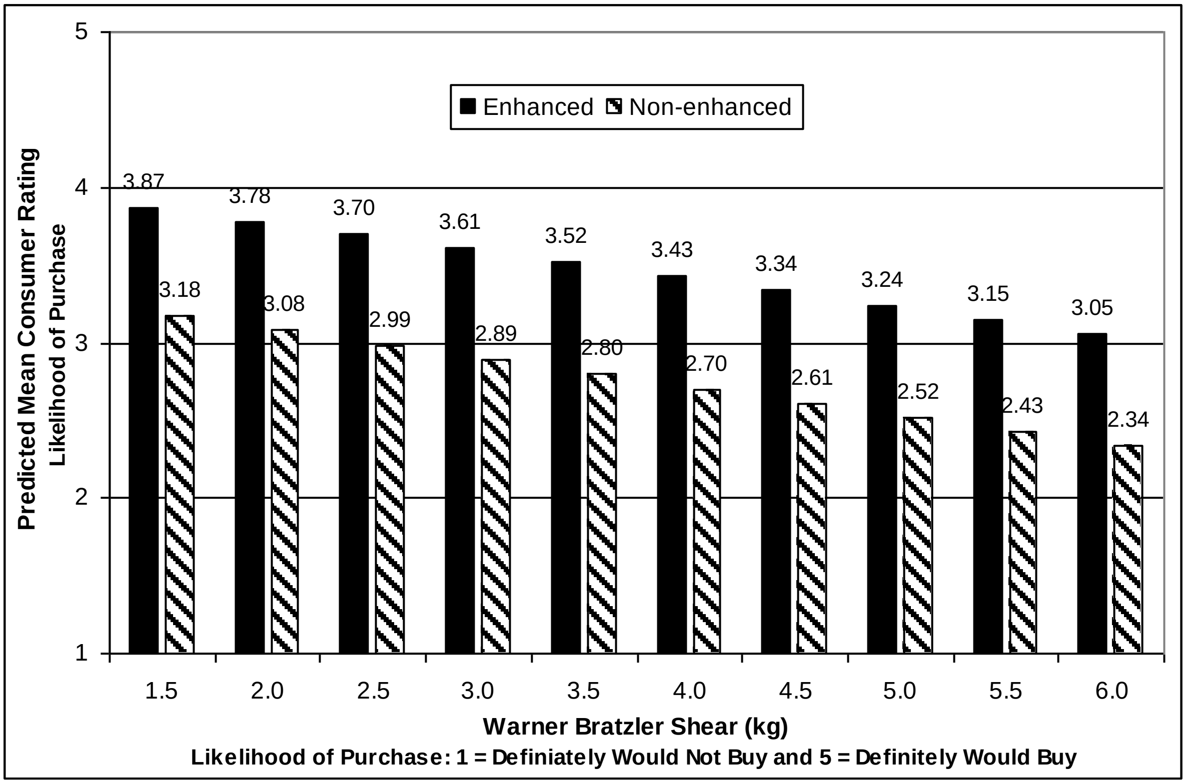


Figure 7: Predicted mean consumer responses for Likelihood of Purchase of non-enhanced and enhanced chops across Warner Bratzler Shear Force levels (N).

Table 18. **A:** Predicted probability[a] of consumer response for Likelihood of Purchase of non-enhanced chops across Warner Bratzler Shear Force values (kg). **B:** Predicted probability of consumer response for Likelihood of Purchase of enhanced chops across Warner Bratzler Shear values (kg).

A	Non-Enhanced				
WBS (kg)[b]	Definitely Would Not Purchase (1)	Probably Would Not Purchase (2)	May or May not Purchase (3)	Probably Would Purchase (4)	Definitely Would Purchase (5)
1.5	0.1053	0.1989	0.2690	0.2684	0.1584
2.0	0.1191	0.2151	0.2724	0.2525	0.1408
2.5	0.1343	0.2312	0.2734	0.2360	0.1250
3.0	0.1512	0.2469	0.2721	0.2192	0.1106
3.5	0.1698	0.2618	0.2683	0.2023	0.0978
4.0	0.1901	0.2756	0.2624	0.1856	0.0863
4.5	0.2123	0.2879	0.2544	0.1695	0.0760
5.0	0.2363	0.2983	0.2446	0.1540	0.0668
5.5	0.2621	0.3067	0.2333	0.1392	0.0587
6.0	0.2896	0.3126	0.2208	0.1254	0.0516

B	Enhanced				
WBS (kg)[b]	Definitely Would Not Purchase (1)	Probably Would Not Purchase (2)	May or May not Purchase (3)	Probably Would Purchase (4)	Definitely Would Purchase (5)
1.5	0.0391	0.0921	0.1857	0.3304	0.3528
2.0	0.0446	0.1031	0.1997	0.3306	0.3220
2.5	0.0508	0.1151	0.2134	0.3281	0.2926
3.0	0.0579	0.1280	0.2264	0.3228	0.2649
3.5	0.0659	0.1418	0.2384	0.3150	0.2389
4.0	0.0750	0.1564	0.2491	0.3049	0.2147
4.5	0.0851	0.1716	0.2581	0.2928	0.1924
5.0	0.0965	0.1875	0.2652	0.2790	0.1718
5.5	0.1092	0.2036	0.2703	0.2638	0.1531
6.0	0.1234	0.2199	0.2730	0.2478	0.1360

[a] To convert to a percent multiply probabilities by 100.

[b] Independent effect of Warner Bratzler shear force with intramuscular fat, Minolta L*, ultimate pH, and cooked temperature modeled effects adjusted to their respective mean value.

Consumer Sensory – Enhanced and Non-Enhanced Conclusions

Consumer perceptions of pork loin eating quality and their likelihood of purchase were clearly improved as the result of enhancement across the range of loin intramuscular fat, pH, and mechanical tenderness tested in the present study. In direct comparisons, increasing cooked temperature of non-enhanced chops resulted in small but consistent reductions in consumer satisfaction, while for enhanced loins as cooked temperature increased consumer ratings were either not changed or were improved slightly indicating a need for different target end-point cooking recommendations for each product if consumers are to capture the most desired eating experience. Intramuscular fat effects were linear in relation to consumer perceptions of eating quality traits, but the incremental impact was very small and only of value when comparing the ends (1% and 6%) of the range. Optimal loin pH values were observed near 5.80 to 6.20 with declines outside the range and most severe decline occurring when evaluated at a pH of 5.40. Tenderness, measured as WBS, had a large impact on consumer perception of eating quality, with large incremental decreases in mean ratings as shear force increased. The challenge in regard to using WBS as an indicator of consumer palatability is the difficulty surrounding the collection of WBS information on cooked product at the industry/processor level. Development of an instrument to estimate tenderness on fresh pork products would be of great value for identification of pork that meets consumer desires for improved tenderness as well as providing a tool to assess environmental and or genetic influences that contribute to variation on pork tenderness.

Trained Sensory Panel - Enhanced and Non-Enhanced Pork Study

Abstract

The impact of variation in fresh pork loin Minolta L* (L*) color, intramuscular fat (IMF), ultimate pH (pH), and cooked Warner Bratzler shear force (WBS) on trained sensory perception of pork chops from non-enhanced (n = 228 loins) and enhanced (n= 227 loins; 10% pump, 0.35% Sodium Phosphate, 0.35% Salt, and 2.25% Potassium Lactate) loins was evaluated at four end-point cooked temperatures (62.8, 68.3, 73.9, and 79.4°C). Dependent trained sensory attributes were analyzed using ordered logistical regression techniques with model independent effects of enhancement treatment, cooked temperature, L*, pH, IMF, and WBS, testing linear, quadratic, and interactive effects among independent effects. Enhancement significantly increased trained sensory tenderness (~0.68 units), chewiness (~0.27 units), juiciness (~.54 units), and saltiness (~3.01 units) predicted mean ratings, measured on 10-point scale, when compared with non-enhanced chops, but did not influence cooked pork fat or cooked pork lean flavor ratings. Increasing cooked temperature resulted in statistically tougher, more chewy, less juicy chops; however, the reduction in sensory ratings were small and of most value when comparing the ends of temperature range evaluated. Increasing WBS resulted in the greatest reduction in predicted mean sensory responses, decreasing tenderness (~ 0.53 units) and juiciness (~0. 22) ratings and increasing chewiness (~0.54 units) for each 4.9 N increase in WBS. Chops with greater ultimate pH (≥6.0) received more favorable tenderness and pork fat flavor ratings when compared with low pH (≤ 5.6) chops. Intramuscular fat and L* influenced tenderness, chewiness, fat flavor and lean flavor with greater IMF (6%) and lower L* (< 46.9)

receiving more favorable ratings when compared with low IMF (1%) and greater L* (> 61.9) chops.

Key Words: Enhancement, Pork Quality, Cooked Temperature,

Trained Sensory – Enhanced and Non-Enhanced Statistical Models

Data were analyzed using STATA software (StataCorp, LP, College Station, TX) and an ordered logistic regression approach to predict probability estimates and mean responses for levels of independent variables tested. Dependent variables included panelist responses to ballot questions for both enhanced and non-enhanced chops originating from the single processing facility and representing approximately 12 of 24 chops consumed within a sensory session. Preliminary models tested the continuous independent variables cooked temperature, pH of the fresh loin, IMF, L*, a*, b*, WBS, NPPC color, and NPPC marbling as linear and quadratic effects and the two-way interactions among independent variables. Enhancement treatment was fit as a fixed variable and interactions between the enhancement treatment and linear independent variables were tested. Panel location was included in all models to account for small, observed differences in panel responses.

Minolta a* and b* were not significant effects and were removed from the final models. Final statistical models for all dependent variables included cooked temperature, enhancement treatment, IMF, pH, quadratic pH (when significant), L*, WBS, and sensory panel effects. Cooked pork lean flavor was only evaluated within the Texas A&M sensory panel. For the dependent variable saltiness, enhancement treatment by IMF and enhancement treatment by WBS interactions were significant and included in final models. Model solutions were entered into Clarify (King et al., 2000) to estimate mean response levels and predicted trained sensory response proportions for, and encompassing the range of, each independent variable tested. Linear correlations among dependent and independent effects were summarized using correlation statistics.

Trained Sensory – Enhanced and Non-Enhanced Results and Discussion

Trained Sensory – Enhanced and Non-Enhanced Loin and Chop Attributes

Descriptive statistics for enhanced and non-enhanced pork loins representing chops used in the trained sensory evaluation (Table1) demonstrate that the sorting procedures utilized were effective in balancing loin quality across the panel locations. Enhancement increased average loin pH by ~ 0.13 units when compared with the fresh state; however, by experimental design, the pH values used in all analyses were from the fresh product to allow for an understanding of raw product quality variation on sensory responses. Shear forces values (Table 2) measured at each end-point cooked temperature on a random chop from the same loin and used as independent variables in statistical analyses in model comparisons were similar across sensory panel locations for both enhanced and non-enhanced loins, verifying a balance across panels. Remembering that loins utilized in the present study were selected to capture the range and combination of attribute values, the numbers presented are not expected to represent an industry average.   Unadjusted means for trained sensory descriptive attributes for each sensory panel location (Tables 3 and 4) provide an overview of the small differences in panel responses across variables and provide evidence for the necessary inclusion of a panel location effect in statistical models to account for the observed source of variation.

Table 1. **A.** Summary of non-enhanced (n = 228) loin quality attributes for loins assigned to trained sensory panel testing locations (Texas A&M University and Iowa State University). **B.** Summary of enhanced (n = 227) loin quality attributes for chops assigned to trained sensory panel testing locations (Texas A&M University and Iowa State University).

	Panel 1 - A&M			Panel 2 – ISU		
Item	Mean	SD	Range	Mean	SD	Range
A Non-Enhanced						
NPPC[a] color, 1 to 6	3.08	1.07	1 – 5	3.01	1.07	1 – 5
NPPC[a] marbling, 1 to 6	2.35	1.18	1 - 5	2.58	1.22	1 – 6
Ultimate pH	5.79	0.21	5.35 - 6.29	5.78	0.23	5.34 - 6.48
Minolta L*	53.76	4.53	43.80 - 65.40	53.76	4.36	44.80 - 64.40
Minolta a*	17.25	1.28	13.60 - 21.02	17.29	1.33	14.00 - 20.90
Minolta b*	4.40	1.09	2.00 - 6.80	4.47	0.97	2.30 - 6.50
Intramuscular Fat, %	2.98	1.38	0.49 - 6.44	3.17	1.29	0.78 - 6.86
Drip loss, %	2.50	2.11	0.00 - 10.62	2.72	2.05	0.00 - 8.20
Cook loss, %	10.33	0.12	0.90 - 22.55	-	-	-
Final pH	-	-	-	-	-	-
B Enhanced						
NPPC[a] color, 1 to 6	3.30	1.01	1 - 6	3.14	1.03	1 – 6
NPPC[a] marbling, 1 to 6	2.64	1.26	1 - 5	2.68	1.25	1 – 6
Ultimate pH	5.80	0.25	5.34 - 6.36	5.77	0.22	5.39 - 6.65
Minolta L*	52.80	4.37	45.00 - 63.30	53.48	4.61	41.00 - 67.50
Minolta a*	16.88	1.16	13.40 - 20.30	16.70	1.45	13.00 - 20.40
Minolta b*	4.30	1.07	2.00 - 7.10	4.38	1.08	2.00 - 7.30
Intramuscular Fat, %	3.22	1.38	0.54 - 6.73	3.09	1.41	0.22 - 6.84
Drip loss, %	3.67	1.38	1.24 - 7.55	3.85	1.46	1.08 - 7.56
Cook loss, %	6.51	0.12	0.83 - 15.23	-	-	-
Final pH	5.93	0.22	5.43 - 6.47	5.89	0.23	5.24 - 6.45

[1]National Pork Producers Council (NPPC) color and marbling standards (2000).

Table 2. **A.** Summary of Warner-Bratzler shear force values for non-enhanced chops assigned to trained sensory testing locations (Texas A&M University and Iowa State University) at four end-point cooked temperatures (n = 114 chops per location per temperature). **B.** Summary of Warner-Bratzler shear force values for enhanced chops assigned to trained sensory testing locations (Texas A&M University and Iowa State University) at four end-point cooked temperatures (n = 113 chops per location per temperature).

	Panel 1 - Texas A&M University				Panel 2 - Iowa State University			
Item	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
A Non-Enhanced								
Warner-Bratzler Shear								
62.8 °C	2.38	0.50	1.29	4.01	2.37	0.52	1.30	4.00
68.3 °C	2.48	0.56	1.41	4.32	2.40	0.51	1.23	3.96
73.9 °C	2.59	0.62	1.45	4.98	2.66	0.72	1.33	5.50
79.4 °C	2.74	0.75	1.53	5.94	2.81	0.76	1.57	5.40
B Enhanced								
Warner-Bratzler Shear								
62.8 °C	1.68	0.42	1.01	3.41	1.67	0.41	0.97	3.33
68.3 °C	1.69	0.46	1.04	3.32	1.61	0.38	1.00	3.45
73.9 °C	1.63	0.36	0.88	3.31	1.63	0.36	0.91	2.90
79.4 °C	1.76	0.42	1.10	3.28	1.71	0.43	1.04	3.55

Table 3. Summary statistics of trained sensory observations for non-enhanced chops evaluated in two trained sensory testing locations (Texas A&M University and Iowa State University).

	Panel 1 - Texas A&M University					Panel 2 - Iowa State University			
Sensory Response Variables[1]	n	Mean	S.D.	Range		n	Mean	S.D.	Range
Juiciness Level									
@ 62.8° C	571	7.35	1.50	3 – 10		570	6.54	1.51	2 – 10
@ 68.3° C	554	7.15	1.51	2 – 10		565	6.10	1.76	1 – 10
@ 73.9° C	565	6.87	1.50	2 – 10		565	5.50	1.83	1 – 10
@ 79.4° C	570	6.62	1.47	2 – 10		570	4.79	1.79	1 – 10
Tenderness Level									
@ 62.8° C	570	7.53	1.36	3 – 10		570	6.94	1.76	2 – 10
@ 68.3° C	555	7.49	1.31	3 – 10		565	6.59	1.87	1 – 10
@ 73.9° C	565	7.43	1.34	3 – 10		565	6.40	1.80	1 – 10
@ 79.4° C	569	7.23	1.37	2 – 10		570	6.24	1.70	1 – 10
Chewiness Level									
@ 62.8° C	571	1.81	0.99	1 – 7		570	2.82	1.31	1 – 9
@ 68.3° C	555	1.75	1.02	1 – 9		565	3.03	1.47	1 – 9
@ 73.9° C	564	1.74	1.13	1 – 9		565	3.16	1.51	1 – 10
@ 79.4° C	569	1.79	1.13	1 – 10		570	3.21	1.52	1 – 10
Fat Flavor Level									
@ 62.8° C	570	1.52	0.65	1 – 7		570	1.99	0.81	1 – 6
@ 68.3° C	553	1.47	0.61	1 – 5		565	1.93	0.79	1 – 5
@ 73.9° C	563	1.43	0.56	1 – 5		565	2.00	0.86	1 – 6
@ 79.4° C	570	1.42	0.56	1 – 3		570	2.04	0.82	1 – 6
Salt Level									
@ 62.8° C	571	1.14	0.36	1 – 3		570	1.02	0.28	1 – 7
@ 68.3° C	553	1.14	0.35	1 – 3		565	1.01	0.08	1 – 2
@ 73.9° C	565	1.15	0.41	1 – 4		565	1.02	0.24	1 – 6
@ 79.4° C	569	1.15	0.45	1 – 7		570	1.02	0.16	1 – 4
Lean Flavor Level									
@ 62.8° C	571	5.67	1.12	1 – 8					
@ 68.3° C	555	5.66	1.11	1 – 8					
@ 73.9° C	565	5.72	1.15	1 – 8					
@ 79.4° C	570	5.69	1.12	1 – 8					

Table 4. Summary statistics of trained sensory observations for enhanced chops evaluated in two trained sensory testing locations (Texas A&M University and Iowa State University).

	Panel 1 - Texas A&M University					Panel 2 - Iowa State University			
Sensory Response Variables[1]	n	Mean	S.D.	Range		n	Mean	S.D.	Range
Juiciness Level									
@ 62.8° C	571	7.78	1.58	1 – 10		566	7.04	1.62	1 – 10
@ 68.3° C	575	7.84	1.54	3 – 10		565	6.94	1.70	1 – 10
@ 73.9° C	555	7.75	1.43	2 – 10		555	6.64	1.74	1 – 10
@ 79.4° C	496	7.54	1.51	3 – 10		569	6.64	1.70	1 – 10
Tenderness Level									
@ 62.8° C	571	8.70	1.19	4 – 10		566	8.34	1.27	3 – 10
@ 68.3° C	575	8.69	1.24	1 – 10		565	8.23	1.26	3 – 10
@ 73.9° C	555	8.66	1.22	5 – 10		555	7.96	1.51	2 – 10
@ 79.4° C	494	8.60	1.25	5 – 10		569	8.08	1.47	2 – 10
Chewiness Level									
@ 62.8° C	570	1.48	1.00	1 – 8		566	2.06	0.74	1 – 5
@ 68.3° C	574	1.49	1.20	1 – 10		565	2.09	0.75	1 – 5
@ 73.9° C	553	1.33	0.79	1 – 10		555	2.13	0.86	1 – 7
@ 79.4° C	496	1.35	0.95	1 – 9		569	2.20	0.86	1 – 7
Fat Flavor Level									
@ 62.8° C	570	1.84	0.75	1 – 6		566	1.73	0.65	1 – 5
@ 68.3° C	573	1.83	0.79	1 – 5		565	1.72	0.59	1 – 3
@ 73.9° C	554	1.72	0.68	1 – 5		555	2.21	0.86	1 – 7
@ 79.4° C	496	1.68	0.66	1 – 4		569	1.77	0.63	1 – 4
Salt Level									
@ 62.8° C	570	2.91	1.47	1 – 10		566	4.62	2.06	1 – 10
@ 68.3° C	574	2.88	1.51	1 – 10		565	4.61	2.08	1 – 10
@ 73.9° C	552	2.81	1.45	1 – 10		555	4.78	2.16	1 – 10
@ 79.4° C	495	2.81	1.52	1 – 10		569	4.56	2.16	1 – 10
Lean Flavor Level									
@ 62.8° C	570	5.57	1.49	2 – 9					
@ 68.3° C	574	5.63	1.38	2 – 9					
@ 73.9° C	555	5.69	1.42	2 – 9					
@ 79.4° C	494	5.78	1.40	2 – 10					

Significance levels established from the ordered logistical regression analysis for each modeled independent effect across the individual dependent trained sensory responses are presented in Table 5. Trained panel location effects were significant for each dependent variable assessed and regression analyses resulted represent appropriate adjustment for the observed effect. A quadratic loin pH effect was observed only for Pork Fat Flavor, and interaction effects among independent variables were only observed for dependent variable Saltiness whereby enhancement by intramuscular fat and enhancement by Warner Bratzler shear interaction effects were identified. Correlations among trained sensory responses (Table 6) are described for both enhanced and non-enhanced chops.

Predicted mean trained sensory responses presented throughout the manuscript reflect the influence of incremental changes in a respective independent variable while maintaining all other independent model effects at their respective mean level. In addition, while the greatest shear force value observed in the present study for enhanced chops was 3.55 kg, predicted trained sensory response ratings were projected beyond the maximum observed level based on model estimates reflecting the range of WBS observed in non-enhanced chops.

Trained Sensory – Enhanced and Non-Enhanced, Enhancement Effects

Within the present study, enhancement of pork loins significantly improved trained sensory assessments of Juiciness, Tenderness, Chewiness, and Saltiness intensities, and had no statistical influence on Fat or Lean Flavor intensities. Because the objectives of the present study were focused on assessing the influence of pork quality variation and cooked temperature on trained sensory perceptions of eating quality in both enhanced and non-enhanced pork, the effects of enhancement are reported throughout the manuscript in relation to their respective influence within each of the primary pork quality indicators (IMF, pH, Minolta L*, and WBS) as well as cooked temperature main effects.

Table 5. Ordered logistic regression significance levels for model tests of independent fresh and cooked pork quality, cooked temperature, and enhancement treatment for dependent trained sensory response variables.

	Trained Sensory Palatability Attributes					
	Level of Tenderness	Level of Chewiness	Level of Juiciness	Level of Fat Flavor	Level of Lean Flavor	Level of Saltines
Independent Variable	P-value	P-value	P-value	P-value	P-value	P-value
Cooked Temperature	0.001	0.022	0.000	0.353	0.016	0.961
Enhancement Treatment	0.000	0.000	0.000	0.109	0.360	0.000
Intramuscular Fat, %	0.017	0.001	0.000	0.000	0.000	0.000
Minolta L* color	0.003	0.000	0.177	0.000	0.000	0.000
Ultimate pH	0.000	0.848	0.074	0.001	0.087	0.159
Warner-Bratzler Shear	0.000	0.000	0.000	0.000	0.712	0.003
Quadratic pH	--	--	--	0.003	--	--
Enhance * IMF	--	--	--	--	--	0.001
Enhance * WBS	--	--	--	--	--	0.001

Table 6. **A:** Simple correlations between trained sensory responses for dependent variables measured on non-enhanced chops. **B:** Simple correlations between trained responses for dependent variables measured on enhanced chops.

Item	Level of Tenderness	Level of Chewiness	Level of Juiciness	Level of Fat Flavor	Level of Lean Flavor
A: Non-Enhanced					
Level of Chewiness	-0.69	-	-	-	-
Level of Juiciness	0.54	-0.43	-	-	-
Level of Fat Flavor	-	0.13	-0.04	-	-
Level of Lean Flavor	0.32	-0.45	0.38	-0.14	-
Level of Saltiness	0.04	-	0.08	0.09	0.18
B: Enhanced					
Level of Chewiness	-0.52	-	-	-	-
Level of Juiciness	0.35	-0.31	-	-	-
Level of Fat Flavor	-0.04	0.10	0.13	-	-
Level of Lean Flavor	0.12	-0.32	0.26	0.19	-
Level of Saltiness	0.06	0.12	-	-0.04	-0.47

Trained Sensory – Enhanced and Non-Enhanced Cooked Temperature Effects

Cooked temperature had the largest significant impact on trained sensory panel assessments of Juiciness intensity and the effect was consistent across both enhanced and non-enhanced chops. Increasing cooked temperature from 62.8° C to 79.4° C, decreased trained sensory juiciness ratings by 7.3% for non-enhanced chops with a similar, 6.9% reduction for enhanced chops (Table 7). Cook loss, a direct measure of moisture loss at each cooked temperature and an indirect assessment of cooked pork juiciness, increased by 3.04% ($P < 0.01$) from mean of 8.98% at 62.8° C to mean of 12.03% at 79.4° C for non-enhanced chops. Cook loss of enhanced chops was significantly less than for non-enhanced chops at each cooked temperature; however, similar to non-enhanced chops, cook loss increased by 2.00% from a mean of 5.77% at 62.8° C to a mean of 7.77% at 79.4° C in the enhanced chops. Dunlavy and Lamkey (1994) reported that non-enhanced chops cooked to a greater temperature had lower juiciness ratings, and Heymann et al. (1990) reported a 13.5% change in juiciness ratings as temperature increased from 65.5 C to 82.2 C and suggested the decrease was likely due to the decline in moisture content of the product.

Mean predicted juiciness ratings were 0.54 units greater (5.4%) for enhanced pork when compared with non-enhanced pork at each cooked temperature, a finding supported by a consistent improvement in cook loss of ~ 3.82% at each cooked temperature when comparing the enhanced (6.49 ± 0.12%) with non-enhanced (10.32 ± 0.12%) chops. In the present study, the beneficial effects of enhancement on water retention are observed through an improvement in juiciness ratings and these findings are supported by finding of Baublits et al. (2006) who showed that percent cooking loss decreased 11.4% when pork chops were enhanced, Sheard et al. (1999) who reported that enhanced pork containing 5% polyphosphate brine improved juiciness ratings by 5.9%, and Prestat et al. (2002) who reported an 8.3% improvement in juiciness ratings for enhanced chops. Greater cook yield for enhanced chops was indicative of the added salt and phosphate brine solution, which helped retain the predicted sensory advantage in juiciness for enhanced chops even at a high end-point temperature.

Table 7. Predicted[a] means for trained sensory assessment of pork eating quality measured on enhanced (E) and non-enhanced (N) pork loins cooked at four end-point temperatures (T).

	Cooked Temperature, °C							
	62.8		68.3		73.9		79.4	
Trained Sensory Response[b]	N	E	N	E	N	E	N	E
Juiciness Level[x,y]	6.41	6.95	6.17	6.72	5.93	6.49	5.68	6.26
Tenderness Level[x,y]	7.13	7.80	7.08	7.76	7.04	7.72	6.99	7.67
Chewiness Level[x,y]	2.76	2.49	2.73	2.46	2.70	2.44	2.67	2.41
Fat Flavor Level	1.83	1.80	1.82	1.79	1.81	1.78	1.81	1.78
Lean/Brothy Flavor Level[x]	5.64	5.59	5.68	5.63	5.72	5.68	5.76	5.72
Saltiness Level[y]	1.12	4.13	1.12	4.13	1.12	4.13	1.12	4.13

[a] Independent effect of cooked temperature with loin intramuscular fat, Minolta L*, ultimate pH, and Warner-Bratzler Shear Force modeled effects adjusted to their respective mean value.
[b] Trained sensory responses assessed using an end-anchored 10-point intensity scale: 1 = dry, tough, not chewy, none, none, and none, respectively; 10 = juicy, tender, very chewy, intense, intense, intense, respectively.
[x] Main effect of Cooked Temperature significant ($P < 0.03$)
[y] Main effect of Enhancement Treatment significant ($P < 0.001$)

The influence of cooked temperature on the distribution of predicted trained panel responses for juiciness level are presented in Table 8. For non-enhanced chops, 50.3% of sensory panel assessments were predicted to rate pork as ≥7 at 62.8° C, declining to 32.1% when temperatures increased to 79.4° C; whereas, for enhanced chops, 64.8% of panelists were predicted to rate chops as ≥7 at 62.8° C, declining to 46.3% with an increase in temperature to 79.4° C. Enhancement clearly shifted the mean and increased the frequency of more favorable sensory responses across all temperatures studied and suggests that enhancement offered additional protection against the detrimental influence of greater cooked temperatures on palatability. Based on trained sensory results, reducing end-point cooked temperatures will improve juiciness of both enhanced and non-enhanced pork chops.

Table 8. **A:** Predicted probability[1] of trained sensory response for Level of Juiciness for non-enhanced chops cooked to four end-point temperatures. **B:** Predicted probability of trained sensory response for Level of Juiciness for enhanced chops cooked to four end-point temperatures.

A	Non-Enhanced									
Cooked Temperature[2]	Dry (1)	2	3	4	5	6	7	8	9	Juicy (10)
62.8 °C	0.0045	0.0158	0.0357	0.0771	0.1245	0.2388	0.2425	0.1686	0.0685	0.0240
68.3 °C	0.0058	0.0202	0.0450	0.0941	0.1438	0.2505	0.2253	0.1420	0.0546	0.0187
73.9 °C	0.0075	0.0257	0.0564	0.1134	0.1623	0.2552	0.2039	0.1177	0.0433	0.0146
79.4 °C	0.0096	0.0328	0.0701	0.1346	0.1787	0.2523	0.1800	0.0964	0.0342	0.0114

B	Enhanced									
Cooked Temperature[2]	Dry (1)	2	3	4	5	6	7	8	9	Juicy (10)
62.8 °C	0.0025	0.0088	0.0204	0.0464	0.0826	0.1915	0.2573	0.2345	0.1133	0.0426
68.3 °C	0.0032	0.0113	0.0260	0.0579	0.0994	0.2141	0.2560	0.2067	0.0920	0.0334
73.9 °C	0.0041	0.0145	0.0329	0.0717	0.1178	0.2332	0.2472	0.1784	0.0741	0.0261
79.4 °C	0.0053	0.0185	0.0415	0.0879	0.1370	0.2471	0.2319	0.1511	0.0592	0.0204

[1] To convert to a percent multiply probabilities by 100.
[2] Independent effect of cooked temperature with intramuscular fat, Minolta L*, ultimate pH, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

Increasing cooked temperature from 62.8° C to 79.4° C, resulted in a significant, but relatively small and likely non-practical reduction in ratings of 0.14 units (1.4%) and 0.13 units (1.3%) in the predicted mean sensory panel ratings for Tenderness (Table 7) of non-enhanced and enhanced chops, respectively. Enhancement increased sensory tenderness responses across the range of cooked temperature evaluated by approximately 0.68 units when compared with the non-enhanced product (Table 7) with overall mean tenderness levels for both enhanced and non-enhanced chops very near or greater than seven on the 10-point scale. The relatively small reduction in Tenderness ratings as cooked temperature increased may be a reflection of the very high overall mean responses that indicated the pork evaluated was generally very tender regardless of end-point cooked temperature. This finding is supported through an observation of the distribution of predicted sensory Tenderness responses (Table 9), whereby upward of 65% and 82% of trained responses were on the 10-point scale for non-enhanced and enhanced chops, respectively. The observed large proportion of predicted responses that were ≥ 7 for the enhanced chops reflects the consistent improvement in Tenderness perception when compared with non-enhanced chops regardless of cooked temperature.

Assessment of chewiness focuses on fiber separation during chewing or mastication of the sample. Cooked temperature, while a significant model effect, had very little practical influence on the predicted mean Chewiness ratings (Table 7) or the distribution of predicted sensory responses (Table 10).

Table 9. **A:** Predicted probability[1] of trained sensory response for Level of Tenderness for non-enhanced chops cooked at four end-point temperatures. **B:** Predicted probability of trained sensory response for Level of Tenderness for enhanced chops cooked at four end-point temperatures.

A	Non-Enhanced									
Cooked Temperature[2]	Tough (1)	2	3	4	5	6	7	8	9	Tender (10)
62.8 °C	0.0003	0.0044	0.0091	0.0293	0.0688	0.1934	0.2954	0.2400	0.1134	0.0461
68.3 °C	0.0003	0.0047	0.0096	0.0309	0.0722	0.1999	0.2967	0.2338	0.1083	0.0437
73.9 °C	0.0003	0.0049	0.0102	0.0326	0.0757	0.2064	0.2977	0.2275	0.1033	0.0413
79.4 °C	0.0003	0.0052	0.0107	0.0344	0.0794	0.2129	0.2982	0.2211	0.0986	0.0391

B	Enhanced									
Cooked Temperature[2]	Tough (1)	2	3	4	5	6	7	8	9	Tender (10)
62.8 °C	0.0001	0.0018	0.0038	0.0126	0.0314	0.1048	0.2303	0.3020	0.2090	0.1041
68.3 °C	0.0001	0.0019	0.0040	0.0133	0.0331	0.1097	0.2364	0.3005	0.2020	0.0989
73.9 °C	0.0001	0.0021	0.0043	0.0141	0.0350	0.1147	0.2423	0.2986	0.1950	0.0939
79.4 °C	0.0001	0.0022	0.0045	0.0149	0.0369	0.1199	0.2480	0.2962	0.1881	0.0891

[1] To convert to a percent multiply probabilities by 100.
[2] Independent effect of cooked temperature with intramuscular fat, Minolta L*, ultimate pH, and Warner Bratzler shear force modeled effects adjusted to their respective mean value.

Enhancement reduced chewiness ratings by 0.26 units when compared with non-enhanced chops, indicating that that enhancement may have led to a reduction in muscle protein integrity resulting in a consistently less chewy pork product across the cooked temperatures evaluated

Neither cooked temperature nor enhancement treatment (Table 7) influenced trained sensory perception of Pork Fat Flavor, the flavor associated with intramuscular fat, in the present study. Renk et al. (1985) reported that because IMF is stored in the inter-fascicular spaces of muscle, which are not necessarily continuous from one end of the muscle to the other, that fat can not easily escape when it is rendered during the cooking process and indicating that increasing cooked temperature should have no effect on intensity of fat flavor. Pork Fat Flavor predicted mean ratings were also very low in the present study with means near 2.00, and representing responses indicative of very little or no-pork fat flavor was observed in the pork served. Results for trained sensory ratings of Pork Lean/Brothy Flavor were similar to Pork Fat Flavor in that enhancement had no significant influence on sensory ratings and, while statistically significant, cooked temperature effects were not of a magnitude that was of practical value when assessed across the incremental changes in cooked temperature. Cooked temperature had no relationship with sensory panel perceptions of Saltiness.

Table 10. **A:** Predicted probability[1] of trained sensory response for Level of Chewiness for non-enhanced chops cooked at four end-point temperatures. **B:** Predicted probability of trained sensory response for Level of Chewiness for enhanced chops cooked at four end-point temperatures.

A	Non-Enhanced									
Cooked Temperature[2]	Not Chewy (1)	2	3	4	5	6	7	8	9	Very Chewy (10)
62.8 °C	0.0929	0.4191	0.2914	0.1120	0.0416	0.0211	0.0119	0.0058	0.0031	0.0010
68.3 °C	0.0966	0.4262	0.2873	0.1085	0.0401	0.0203	0.0114	0.0056	0.0030	0.0010
73.9 °C	0.1005	0.4331	0.2831	0.1051	0.0386	0.0195	0.0109	0.0053	0.0029	0.0009
79.4 °C	0.1045	0.4399	0.2788	0.1018	0.0371	0.0187	0.0105	0.0051	0.0027	0.0009

B	Enhanced									
Cooked Temperature[2]	Not Chewy (1)	2	3	4	5	6	7	8	9	Very Chewy (10)
62.8 °C	0.1373	0.4825	0.2441	0.0799	0.0280	0.0139	0.0077	0.0037	0.0020	0.0007
68.3 °C	0.1425	0.4875	0.2390	0.0772	0.0270	0.0133	0.0074	0.0036	0.0019	0.0006
73.9 °C	0.1479	0.4921	0.2338	0.0745	0.0259	0.0128	0.0071	0.0034	0.0018	0.0006
79.4 °C	0.1534	0.4965	0.2286	0.0719	0.0249	0.0123	0.0068	0.0033	0.0018	0.0006

[1] To convert to a percent multiply probabilities by 100.
[2] Independent effect of cooked temperature with Warner Bratzler shear force, intramuscular fat, Minolta L*, and ultimate pH modeled effects adjusted to their respective mean value.

Trained Sensory – Enhanced and Non-Enhanced Loin WBS Effects

The relationship between WBS, an objective, mechanical assessment of a human's perception of tenderness, and the mean subjective trained sensory Tenderness ratings (Figure 1) were indicative of the moderate to strong, negative relationship between the traits for non-enhanced (r = - 0.42) and a moderate, negative relationship for enhanced chops (r = - 0.27). These relationships were verified in relation to the model effects which indicated a linear reduction in the mean sensory Tenderness rating as WBS increased for the range of WBS evaluated. Caine et al. (2003) had previously reported a large negative (r = -0.72) relationship between WBS and perceived tenderness, a value greater than observed in the present study. When comparing the predicted mean responses for both enhanced and non-enhanced chops at the 1.5 and 6.0 kg, sensory Tenderness ratings declined by ~ 4.34 units (43.4%) when WBS reached 6.0 kg, an incremental change in sensory ratings of 0.33 units for each 0.50 kg increase in WBS. Sensory panelists rated Tenderness of enhanced pork approximately 0.70 units greater when compared with non-enhanced pork at equal WBS values, a percentage improvement in Tenderness ratings similar to a report by Sheard et al. (1999) where enhanced chops were reported to be 10.5% more tender when compared with non-enhanced chops. To achieve a predicted mean rating of 5 or greater non-enhanced chops required a WBS of ≤ 4 kg, while to achieve a comparable response for enhanced chops, WBS could achieve a level of nearly 5 kg.

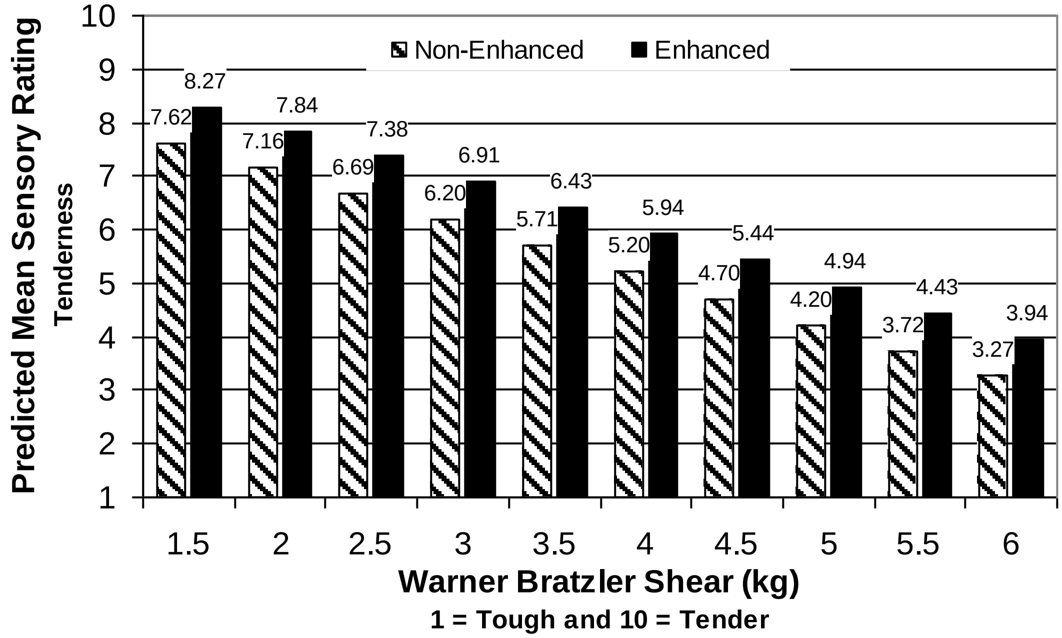


Figure 1. Predicted mean trained sensory responses for Level of Tenderness for non-enhanced and enhanced chops across Warner Bratzler Shear Force levels (kg).

Review of the distribution of predicted sensory panel ratings for Tenderness at incremental WBS values (Table 11) clearly indicates that chops with less WBS increased the proportion of ratings on the upper (more tender) end of the sensory scale. For the most tender WBS category (1.5 kg), 81.2% and 91.2% of sensory ratings for Tenderness were predicted to be ≥ 7 for non-enhanced and enhanced chops, respectively. The predicted proportions declined by ~7.9% for each 0.50 kg incremental increase in WBS, reducing the proportion of ratings predicted to be ≥ 7 to less than 1% at the toughest WBS category (6.0 kg) tested.

As Warner-Bratzler shear force increased, sensory chewiness ratings increased in the present study, indicating chops with greater WBS were chewier (Figure 2). The palatability trait chewiness is an indicator of the ease of

Table 11. **A:** Predicted probability[1] of trained sensory response for Level of Tenderness for non-enhanced chops across Warner-Bratzler shear force levels. **B:** Predicted probability of trained sensory response for Level of Tenderness for enhanced chops across Warner-Bratzler shear force levels.

A	Non-Enhanced									
WBS[2] (N)	Tough (1)	2	3	4	5	6	7	8	9	Tender (10)
14.7	0.0002	0.0023	0.0048	0.0158	0.0391	0.1258	0.2541	0.2932	0.1807	0.0841
19.6	0.0003	0.0042	0.0087	0.0281	0.0662	0.1884	0.2940	0.2447	0.1174	0.0482
24.5	0.0005	0.0076	0.0155	0.0487	0.1069	0.2533	0.2904	0.1785	0.0715	0.0271
29.4	0.0009	0.0137	0.0275	0.0819	0.1598	0.2965	0.2452	0.1176	0.0417	0.0151
34.3	0.0016	0.0246	0.0476	0.1305	0.2139	0.2967	0.1807	0.0721	0.0237	0.0084
39.2	0.0030	0.0437	0.0798	0.1915	0.2482	0.2538	0.1198	0.0423	0.0133	0.0046
44.1	0.0053	0.0762	0.1265	0.2503	0.2448	0.1890	0.0738	0.0242	0.0074	0.0026
49.0	0.0097	0.1290	0.1841	0.2828	0.2057	0.1263	0.0434	0.0136	0.0041	0.0014
53.9	0.0174	0.2087	0.2376	0.2721	0.1505	0.0782	0.0248	0.0076	0.0023	0.0008
58.8	0.0311	0.3154	0.2643	0.2241	0.0991	0.0462	0.0140	0.0042	0.0013	0.0004

B	Enhanced									
WBS[2] (N)	Tough (1)	2	3	4	5	6	7	8	9	Tender(10)
14.7	0.0001	0.0010	0.0020	0.0067	0.0171	0.0610	0.1601	0.2882	0.2831	0.1807
19.6	0.0001	0.0018	0.0037	0.0121	0.0301	0.1011	0.2256	0.3028	0.2145	0.1084
24.5	0.0002	0.0032	0.0066	0.0215	0.0519	0.1575	0.2797	0.2714	0.1453	0.0628
29.4	0.0004	0.0058	0.0118	0.0377	0.0860	0.2237	0.2980	0.2102	0.0909	0.0356
34.3	0.0007	0.0104	0.0210	0.0645	0.1338	0.2805	0.2705	0.1447	0.0540	0.0199
39.2	0.0012	0.0187	0.0369	0.1057	0.1895	0.3026	0.2118	0.0914	0.0310	0.0111
44.1	0.0022	0.0334	0.0629	0.1619	0.2360	0.2784	0.1470	0.0546	0.0175	0.0061
49.0	0.0040	0.0588	0.1027	0.2243	0.2515	0.2205	0.0934	0.0315	0.0098	0.0034
53.9	0.0073	0.1011	0.1563	0.2722	0.2275	0.1544	0.0560	0.0178	0.0054	0.0019
58.8	0.0132	0.1676	0.2143	0.2827	0.1770	0.0987	0.0324	0.0100	0.0030	0.0010

[1] To convert to a percent multiply probabilities by 100.
[2] Independent effect of Warner Bratzler shear force (WBS) with cooked temperature, intramuscular fat, Minolta L*, and ultimate pH modeled effects adjusted to their respective mean value.

mastication and products with greater levels of connective tissue will have a higher degree of chewiness. Warner-Bratzler shear is also an indirect measurement of the quantity of connective tissue. Chewiness ratings increased for both enhanced and non-enhanced chops suggesting that the quantity of connective tissue may be greater, regardless of enhancement, in chops with greater WBS. Predicted mean responses for Chewiness rating of chops increased 38.6% and 38% for non-enhanced and enhanced chop, respectively, as WBS values increased from 1.5 to 6.0 kg. The large incremental change in chewiness is similar to the direct relationship observed between WBS and sensory Tenderness discussed previously.

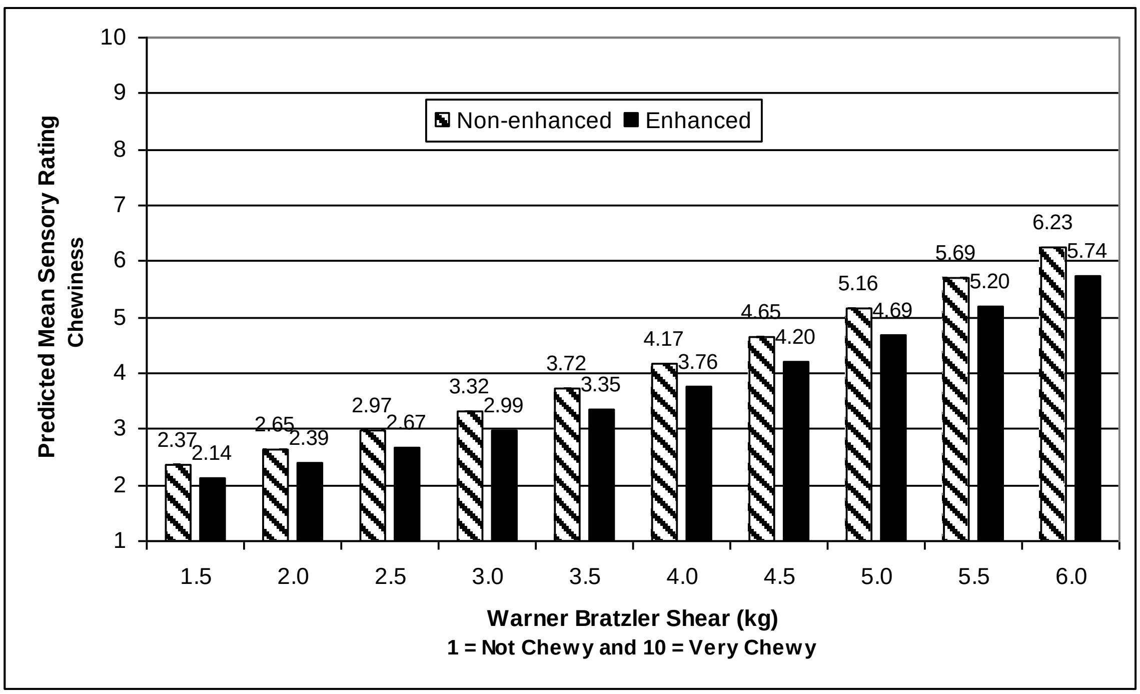


Figure 2. Predicted mean trained sensory responses for Level of Chewiness for non-enhanced and enhanced chops across Warner Bratzler Shear Force levels (kg).

Predicted mean sensory responses for Juiciness declined in equal increments for non-enhanced and enhanced chops as WBS increased (Figure 3), with an incremental WBS increase of 0.5 kg resulting in concurrent -0.22 unit decrease in Juiciness rating.

The relationship described indicates juiciness, while not a direct measure of tenderness, was influenced by the perceived level of tenderness/toughness. In addition, enhancement improved predicted mean juiciness scores by approximately 0.55 units across all WBS levels on the 10-unit scale. Hodgson et al. (1991) reported a significant negative ($r = -0.39$) relationship between WBS and juiciness ratings, a finding that was similar to the correlation between juiciness rating and WBS ($r = -0.26$) for the non-enhanced pork tested in the present study. Of note, there was no significant statistical correlation between Juiciness rating and WBS for enhanced product in the present study. When assessing the predicted mean responses, non-enhanced chops received a rating of > 5 on the 10 point scale for Juiciness when WBS value was ≤ 4.0 kg, while the enhanced chops maintained a predicted mean rating of > 5 for Juiciness at a WBS value of 5.5 kg or less. The observed relationship between sensory assessment of Juiciness and WBS may be related to the moderate correlation between sensory ratings for tenderness and juiciness in the non-enhanced ($r = 0.54$) and enhanced ($r = 0.35$) chops, with the effect simply being a correlated response to the observed influence of WBS on perception of Tenderness as previously mentioned. When assessing the distribution of sensory panel Juiciness ratings (Table 12), the enhanced chops maintained a greater percentage (~ 12%) of ratings within the ≥ 7 response categories when compared with non-enhanced chops observed at the same WBS.

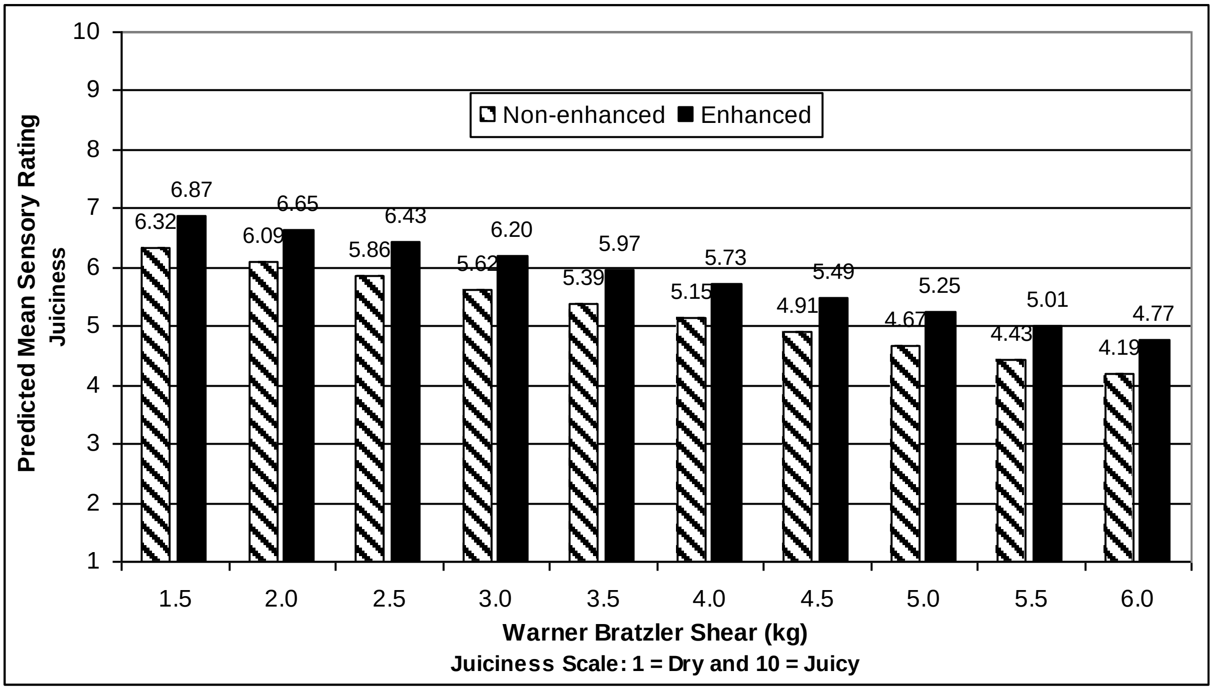


Figure 3: Predicted mean trained sensory responses for Level of Juiciness for non-enhanced and enhanced chops across Warner Bratzler Shear Force levels (kg).

Trained panel ratings were consistent with respect to differentiating between enhanced and non-enhanced pork across the WBS range; however, the reason for the improved Tenderness and Chewiness ratings for enhanced product are somewhat difficult to interpret given that the direct comparisons made along the scale of WBS represent measured WBS levels for the product tested. In other words, the perception of tenderness and chewiness improved for enhanced pork when both enhanced and non-enhanced pork were compared at equal WBS levels, suggesting that trained panelists were influenced in a positive direction by attributes other than tenderness or chewiness alone when rating the chops in the present study. It is possible that the observed improvement in Juiciness ratings as a result of enhancement may have carried over to also influence Tenderness and Chewiness ratings.

Table 12. **A:** Predicted probability[1] of trained sensory response for Level of Juiciness for non-enhanced chops across Warner-Bratzler shear force levels. **B:** Predicted probability of trained sensory response for Level of Juiciness for enhanced chops across Warner-Bratzler shear force levels.

A	Non-Enhanced									
WBS[2] (N)	Dry (1)	2	3	4	5	6	7	8	9	Juicy (10)
1.5	0.0050	0.0172	0.0388	0.0830	0.1314	0.2437	0.2369	0.1588	0.0632	0.0219
2.0	0.0063	0.0218	0.0484	0.1001	0.1498	0.2528	0.2188	0.1339	0.0507	0.0173
2.5	0.0080	0.0275	0.0600	0.1192	0.1672	0.2551	0.1974	0.1115	0.0405	0.0136
3.0	0.0102	0.0347	0.0738	0.1398	0.1821	0.2505	0.1742	0.0917	0.0323	0.0107
3.5	0.0130	0.0436	0.0900	0.1611	0.1934	0.2394	0.1508	0.0748	0.0256	0.0084
4.0	0.0165	0.0545	0.1086	0.1821	0.1998	0.2229	0.1283	0.0605	0.0203	0.0066
4.5	0.0209	0.0678	0.1294	0.2012	0.2007	0.2025	0.1076	0.0487	0.0160	0.0052
5.0	0.0265	0.0839	0.1519	0.2170	0.1960	0.1799	0.0891	0.0389	0.0126	0.0041
5.5	0.0336	0.1031	0.1753	0.2280	0.1862	0.1566	0.0730	0.0310	0.0100	0.0032
6.0	0.0424	0.1255	0.1984	0.2331	0.1723	0.1339	0.0593	0.0246	0.0078	0.0025

B	Enhanced									
WBS[2] (N)	Dry (1)	2	3	4	5	6	7	8	9	Juicy (10)
1.5	0.0027	0.0096	0.0223	0.0503	0.0884	0.1999	0.2577	0.2247	0.1052	0.0391
2.0	0.0035	0.0122	0.0280	0.0621	0.1052	0.2207	0.2539	0.1976	0.0859	0.0309
2.5	0.0044	0.0155	0.0351	0.0760	0.1231	0.2377	0.2435	0.1706	0.0696	0.0244
3.0	0.0057	0.0196	0.0439	0.0921	0.1416	0.2495	0.2275	0.1448	0.0560	0.0192
3.5	0.0072	0.0248	0.0545	0.1104	0.1596	0.2549	0.2073	0.1212	0.0449	0.0152
4.0	0.0092	0.0313	0.0673	0.1304	0.1758	0.2534	0.1847	0.1003	0.0358	0.0119
4.5	0.0117	0.0393	0.0824	0.1515	0.1889	0.2451	0.1612	0.0821	0.0284	0.0094
5.0	0.0148	0.0493	0.0999	0.1728	0.1976	0.2309	0.1382	0.0666	0.0225	0.0074
5.5	0.0188	0.0615	0.1198	0.1929	0.2010	0.2120	0.1166	0.0537	0.0178	0.0058
6.0	0.0239	0.0763	0.1416	0.2104	0.1988	0.1902	0.0971	0.0431	0.0141	0.0046

[1] To convert to a percent multiply probabilities by 100.
[2] Independent effect of Warner Bratzler shear force (WBS) with intramuscular fat, Minolta L*, ultimate pH, and cooked temperature modeled effects adjusted to their respective mean value.

Trained Sensory – Enhanced and Non-Enhanced Loin pH Effects

Loin pH had no measurable influence on variation in Juiciness, Chewiness, Lean/Brothy Flavor or Saltiness ratings (Table 13) of either non-enhanced or enhanced chops in the present study, although enhancement significantly improved predicted mean Juiciness (+ 0.56 units), Chewiness (- 0.26 units) and Saltiness (+ 3.04 units) ratings at each level of loin pH assessed.

Predicted mean responses (Table 13) for sensory Tenderness ratings were assessed at 0.20 unit intervals across the pH range of 5.40 to 6.40. An increase in loin pH from 5.40 to the upper level of 6.40 improved tenderness ratings by 0.64 units (6.4%) and 0.67 units (6.7%) for enhanced and non-enhanced chop, respectively. Enhancement improved Tenderness ratings in an additive (~ + 0.66 units) manner at each pH level resulting in the predicted mean response of a non-enhanced chop at a pH or 5.40 (mean = 7.47) to be nearly equivalent to the predicted mean response of an enhanced chop with an ultimate pH of 5.40. Lonergan et al. (2007) reported similar relationships between loin pH and sensory evaluation of tenderness in non-enhanced chops, whereby increasing pH from a classification of < 5.5 up to a classification level of > 5.95 improved tenderness ratings by 10%. Pork with greater ultimate pH have been thought to have improved tenderness as a result of a faster rate of rigor mortis resulting in a more rapid completion of the rigor phase, thus allowing more time for the post-rigor proteolytic degradation to occur (Gardner et al., 2005). Huff-Lonergan et al. (2002) reported a moderate relationship (r = 0.27) between ultimate pH and tenderness rating, while in contrast Davis et al. (1975) and DeVol et al. (1988) reported no significant correlation between pH and tenderness. In the present study, ultimate pH had a moderate and positive association with Tenderness ratings for non-enhanced chops (r = 0.26) and a smaller, positive relationship when evaluated for enhanced chops (r = 0.13).

Ultimate pH affected trained sensory ratings for Pork Fat Flavor in a non-linear manner as described in Table 13. As ultimate pH increased from 5.4 to 6.4 the predicted mean sensory ratings improved approximately 0.36 units (3.6%); however, the quadratic relationship observed provided grater incremental changes in sensory assessment of pork fat flavor as pH was increased from 5.4 to 5.6 (0.13 unit increase) followed by a 0.10 unit increase when pH was increased from 5.6 to 5.8 and a smaller effect and the development of a plateau in Pork Fat Flavor ratings for pH in the range of 6.0 to 6.4. Previous research has shown that chops with a greater pH have beneficial impacts on water-holding capacity and cook yield (Lonergan et al., 2007), resulting in a product with a greater moisture content. At greater pH levels, pork with more water-holding capacity may also be juicier, allowing for a release of more natural juices during sensory evaluation. Following this line of thought, within the cooked temperature range studied (68.2 to 79.4 C) pork fat is in a semi-solid/liquid state, and the liquefied fat may mix with the natural juices, carrying fat flavor components along and resulting in a more intense flavor rating. Huff-Lonergan et al. (2002) reported that pH was significantly related to flavor (r = 0.27). In the present study, ultimate pH and Pork Fat Flavor were significantly, but weakly correlated (r = 0.09), indicating that while ultimate pH played an important role in Pork Fat Flavor intensity, other inherent quality factors are also contributing to variation in flavor intensity. In contrast to pork fat flavor assessment results, there was no statistical impact of variation in ultimate pH (Table 13) on ratings for Pork Lean/Brothy Flavor.

Table 13. Predicted[a] means for trained sensory panel assessment of pork eating quality of enhanced (E) and non-enhanced (N) pork loins measured across loin ultimate pH levels.

	Loin pH											
	5.40		5.60		5.80		6.00		6.20		6.40	
Trained Sensory Response[b]	Non	Enh	Non	Enh	Non	Enh	Non	Enh	Non	Enh	Non	Enh
Juiciness Level[x]	5.97	6.53	6.01	6.57	6.05	6.61	6.09	6.64	6.12	6.68	6.16	6.72
Tenderness Level[xy]	6.80	7.49	6.94	7.62	7.07	7.75	7.21	7.88	7.34	8.00	7.47	8.13
Chewiness Level[x]	2.71	2.44	2.71	2.45	2.71	2.45	2.72	2.45	2.72	2.46	2.72	2.46
Fat Flavor Level[xyz]	1.68	1.65	1.81	1.78	1.91	1.87	1.98	1.95	2.03	1.99	2.04	2.01
Lean/Brothy Flavor Level	5.77	5.73	5.73	5.69	5.70	5.65	5.66	5.61	5.62	5.57	5.58	5.53
Saltiness Level[x]	1.13	4.21	1.13	4.17	1.12	4.13	1.12	4.08	1.11	4.04	1.11	4.00

[a] Independent effect of loin ultimate pH with cooked temperature, intramuscular fat, Minolta L*, ultimate pH, and Warner-Bratzler Shear Force modeled effects adjusted to their respective mean value.
[b] Trained sensory responses assessed using an end-anchored 10-point intensity scale: 1 = dry, tough, not chewy, none, none, and none, respectively; 10 = juicy, tender, very chewy, intense, intense, intense, respectively.
[x] Main effect of Enhancement significant ($P < 0.01$)
[y] Main effect of Loin pH significant ($P < 0.01$)
[z] Quadratic effect of Loin pH significant ($P < 0.01$)

Trained Sensory – Enhanced and Non-Enhanced Loin Intramuscular Fat Effects

Intramuscular fat, while a significant model effect, had a very small, positive impact (Table 14) on trained sensory assessment of loin Tenderness, increasing predicted mean responses by 0.14 units (1.4 %) for non-enhanced and 0.13 units (1.3%) for enhanced chops when comparing 1% and 6% IMF levels. Results from the present study are supported by results of Rincker et al. (2008) reporting that IMF had little effect on consumer tenderness scores (R^2 = 0.05) when assessed on non-enhanced chops cooked to 71° C. In contrast, the relatively small effect observed in the present study is substantially less than results presented by Brewer et al. (2001) that indicated that increasing IMF from <1.0% to 3.5% increased tenderness scores by 18.8%, and a study by Fernandez et al. (1999) reported that increasing IMF levels above 2.25% had a beneficial impact on texture scores. Chops from loins represented in the present study were also evaluated under similar testing conditions at the consumer level and the results (data not presented) indicated that IMF had no impact on the consumer's perception of tenderness. Fortin et al. (2005) and DeVol et al. (1988) have previously reported that a threshold level of pork IMF is necessary to ensure an acceptable eating experience. Data from the present study do not support these findings and suggest that in relation to perceptions of tenderness, level of IMF is likely independent. Results of the present study suggest that enhancement of pork, regardless of IMF content in the raw product, improved tenderness levels consistently (~ 0.70 units) on the 10-point scale.

Table 14. Predicted[a] means for trained sensory panel assessment of pork eating quality of enhanced (E) and non-enhanced (N) pork loins measured across loin intramuscular fat levels.

	Intramuscular Fat, %											
	1		2		3		4		5		6	
Trained Sensory Response[b]	N	E	N	E	N	E	N	E	N	E	N	E
Juiciness Level[xy]	5.92	6.48	5.98	6.54	6.04	6.60	6.11	6.66	6.17	6.72	6.23	6.78
Tenderness Level[xy]	7.00	7.68	7.03	7.71	7.05	7.73	7.08	7.76	7.11	7.79	7.14	7.81
Chewiness Level[xy]	2.79	2.52	2.75	2.49	2.72	2.45	2.68	2.42	2.65	2.39	2.61	2.36
Fat Flavor Level[y]	1.76	1.73	1.79	1.76	1.81	1.78	1.84	1.81	1.87	1.83	1.89	1.86
Lean/Brothy Flavor Level[y]	5.51	5.47	5.60	5.56	5.69	5.65	5.78	5.73	5.86	5.82	5.95	5.90
Saltiness Level[xyz]	1.17	4.28	1.13	4.13	1.10	3.99	1.08	3.84	1.06	3.70	1.04	3.57

[a] Independent effect of loin intramuscular fat with cooked temperature, Minolta L*, ultimate pH, and Warner-Bratzler Shear Force modeled effects adjusted to their respective mean value.
[b] Trained sensory responses assessed using an end-anchored 10-point intensity scale: 1 = dry, tough, not chewy, none, none, and none, respectively; 10 = juicy, tender, very chewy, intense, intense, intense, respectively.
[x] Main effect of Enhancement significant ($P < 0.01$)
[y] Main effect of Intramuscular Fat Percentage significant ($P < 0.05$).
[z] Interaction effect of Intramuscular Fat Percentage x Enhancement significant ($P < 0.01$)

Increasing IMF levels resulted in a significant linear reduction in predicted mean Chewiness ratings (Table 14) across the range of IMF evaluated; however, the magnitude of the effect was very small as noted by a reduction in Chewiness ratings of approximately 1.8% for both enhanced and non-enhanced chops as IMF increased from 1% to 6%. The small effect observed in the present study was indicative of the near zero correlations between Chewiness ratings and IMF for non-enhanced (r = 0.01) and enhanced (r = - 0.05) chops. In contrast, Candel-Potoar et al. (1998) reported that lipid content influences sensory perception of texture and Renk et al. (1985) suggested that IMF can be related to texture because of differing biological properties of fat when compared to protein. Wood et al. (1999) reported that IMF accumulates within the perimysial connective tissue, the tissue surrounding each muscle bundle, and that with high degrees of intramuscular fat (>200 mg/g) it is possible that fibrous proteins are diluted by soft fat, resulting in textural differences. Moreover, Fernandez et al. (1999) reported that increasing IMF levels to > 2.25% had a beneficial impact on texture scores.

For both non-enhanced and enhanced chops, a significant linear increase (~ 3.0% or 0.31 units) in predicted mean sensory rating for Juiciness was observed when comparing the ends (1% vs. 6%) of the IMF range studied. However, while the observed increase was statistically significant, the incremental increase in trained sensory ratings for Juiciness when changing IMF levels by 1% were very small and would be of limited practical use to the industry unless comparisons are made between populations having large differences in IMF or when sorting pork into largely divergent IMF categories for specific market targets. Enhancement improved mean Juiciness ratings by 0.56 units when compared with non-enhanced chops at each level of IMF, resulting in greater predicted mean ratings for enhanced chops at all IMF levels evaluated when compared with IMF of non-enhanced chops at the most favorable IMF level (6%). While IMF had a statistically significant influence on Pork Fat Flavor in the present data set, the difference observed over the range of IMF was very small and of limited practical value when attempting to differentiate acceptability from the trained panel observations. An important aspect to remember when assessing the relationship between IMF and Pork Fat Flavor is the overall mean responses were near 2.0 on the 10-point scale and a large proportion of ratings were 1 (none) indicating that the pork chops consumed, regardless of enhancement, had very little Pork Fat Flavor. Previous research has reported that IMF may account for 52% of the variation in flavor intensity (Platter et al., 2003), while Fernandez et al. (1999) reported that IMF needed to reach a threshold value of 2% IMF before there were any noticeable beneficial effects on flavor intensity. Brewer et al. (2001) reported that as IMF increased from <1% to 3.5%, flavor ratings improved by 8%. Fernandez et al. (1999) also reported that increasing IMF above 3.25% did not improve the linear benefits in detectable flavor of pork. While it was thought that increasing IMF levels would have a beneficial impact on Pork Fat Flavor ratings when evaluated by a trained sensory panel, data from the present study show that incremental changes, and changes across the IMF range, are not of a magnitude to be of practical value to the industry when attempting to differentiate pork fat flavor levels.

Trained sensory predicted mean ratings of Lean Pork/Brothy Flavor increased as the level of IMF increased across the range (1 vs. 6%) resulting in an increase of approximately 0.44 units (4.4%) when comparing the extremes (Table 14). While it is thought that increasing IMF levels would have little effect on Lean Pork/Brothy Flavor, flavor components within the lipid component are likely beneficial to overall pork flavor, likely resulting in the higher flavor intensity ratings when evaluated by a trained sensory panel.

Trained Sensory – Enhanced and Non-Enhanced Minolta L Effects*

Increasing Minolta L* resulted in a significant, but small negative change in sensory panelist's ratings for Tenderness (Table 15). From dark to pale on the L* range, predicted mean sensory ratings decreased by 0.25 units (2.5%) for non-enhanced chops and 0.24 units (2.4%) for enhanced chops indicating that as pork L* increased (paler) sensory ratings indicated a reduction in tenderness. Hodgson et al. (1991) reported a significant negative correlation (r = - 0.57) between color and WBS indicating that as pork lean color became darker, WBS decreased indicating an improvement in tenderness. In the present study, the correlation between L* and Tenderness was rather low for non-enhanced (r = - 0.15) and enhanced (r = -0. 10) chops. Correlations between WBS and sensory Tenderness ratings for non-enhanced (r = 0.07) and enhanced (r = 0.10) were also very small in the present study. Chops from loins with greater L* values (paler) produced pork with predicted mean chewiness scores that were greater (Table 13) than chops with lower L* values (darker).

Table 15. Predicted[a] means for trained sensory panel assessment of pork eating quality of enhanced (E) and non-enhanced (N) pork loins measured across loin Minolta L* levels

	Loin Minolta L*											
	46.9		49.9		53.9		57.9		61.9		65.0	
Trained Sensory Response[b]	Non	Enh	Non	Enh	Non	Enh	Non	Enh	Non	Enh	Non	Enh
Juiciness Level[x]	6.10	6.66	6.08	6.63	6.05	6.61	6.02	6.58	5.99	6.55	5.96	6.53
Tenderness Level[xy]	7.15	7.82	7.11	7.78	7.05	7.73	7.00	7.68	6.94	7.62	6.90	7.58
Chewiness Level[xy]	2.54	2.29	2.62	2.36	2.73	2.46	2.84	2.56	2.96	2.67	3.06	2.76
Fat Flavor Level[y]	1.76	1.73	1.79	1.76	1.82	1.79	1.86	1.82	1.89	1.86	1.92	1.88
Lean/Brothy Flavor Level[y]	5.90	5.86	5.81	5.77	5.69	5.64	5.56	5.51	5.43	5.38	5.32	5.28
Saltiness Level[xy]	1.05	3.26	1.07	3.58	1.11	4.02	1.17	4.50	1.25	4.99	1.33	5.39

[a] Independent effect of loin Minolta L* with cooked temperature, intramuscular fat, ultimate pH, and Warner-Bratzler Shear Force modeled effects adjusted to their respective mean value.

[b] Trained sensory responses assessed using an end-anchored 10-point intensity scale: 1 = dry, tough, not chewy, none, none, and none, respectively; 10 = juicy, tender, very chewy, intense, intense, intense, respectively.

[x] Main effect of Enhancement significant ($P < 0.01$)

[y] Main effect of Minolta L* significant ($P < 0.01$).

Predicted mean trained sensory ratings for lean pork flavor at incremental L* values are presented in Table 15. The significant negative relationship indicates that as L* reflectance increases (paler) the intensity of lean flavor declines. Across the Minolta L* range (46.9 to 65.0), lean flavor intensity declined 0.58 units (5.8%). The change in intensity across the large L* range indicates that trained sensory panelists were able to verify that darker colored pork had more lean flavor; however, slight changes in color (3 to 4 L* units) were more difficult to distinguish.

Chops with greater L* (paler color) were predicted to have greater predicted mean sensory panel saltiness ratings reflecting a 21.7% (2.17 units) increase in saltiness rating when compared with chops with lesser L* (darker) levels in the fresh state. The results observed may be related to the amount of loin drip loss and binding of the salt to the bound molecules of water within the chop. In the present study, enhanced loins with L* values of 60 to 65 had 4.39% drip loss while enhanced drip loss of loins with L* values of less the 46.9 was reduced to 2.80%. Drip loss represents a loss in non-bound water. The enhancement solution contains salt and phosphate which bind to the protein matrix rather than the non-bound water. Therefore, paler enhanced loins (greater L*) having a greater drip loss (loss of non-bound water) percentage, would have a corresponding increase in salt concentration in the loin. In contrast, darker enhanced loins (lower L*) would have more have a greater proportion of non-bound water that may dilute expression of saltiness within the pork.

Trained Sensory – Enhanced and Non-Enhanced Saltiness Interaction Effects

Significant statistical interaction effects between trained sensory perception of Saltiness with pork quality traits IMF (Table 14), Minolta L* (Table 15) and WBS (Figure

4) were a function of predicted mean Saltiness levels increasing for enhanced chops as Minolta L* increased (chops became paler), WBS increased (chops became tougher), and IMF decreased (less IMF) while the predicted mean Saltiness level for non-enhanced chops remained consistently near a rating of one (none) on the 10-point scale. Observation of the distribution of Saltiness ratings provided evidence of the enhancement effect (Figure 5) whereby 92.7% of non-enhanced chops were rated as 1 (None) and 6.8% were rated as 2 with the balance (0.50%) rated as 3 on the 10-point scale indicating essential no variance for saltiness in non-enhanced chops. In contrast, enhanced chop responses followed a more normal distribution, with a mean response of near 3.0 and very limited skewness. The difference in distributions of responses between enhanced and non-enhanced chops created an interaction effect, whereby enhanced product was influenced by changes in both IMF, WBS, and Minolta L* while the non-enhanced chop predicted mean responses centered near one (none) regardless of the level of quality assessed. Predicted mean trained sensory ratings for level of saltiness at individual levels of IMF (Table 14) show a negative relationship within the enhanced chops, across the IMF range (1% to 6%) the intensity of saltiness declines 0.86 units (8.6%) for enhanced chops.

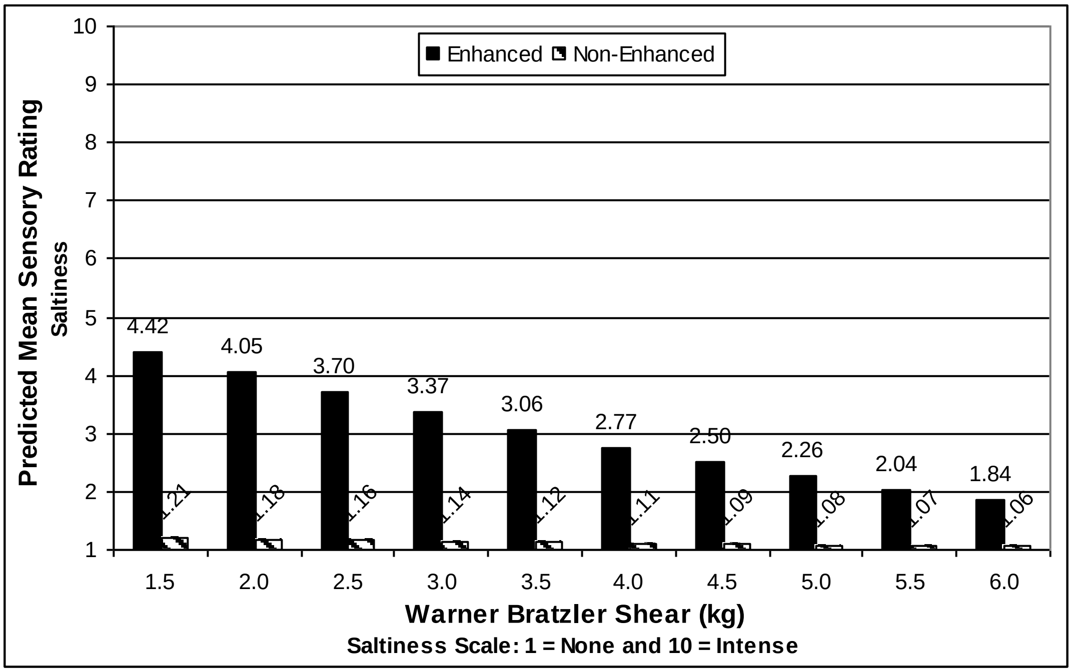
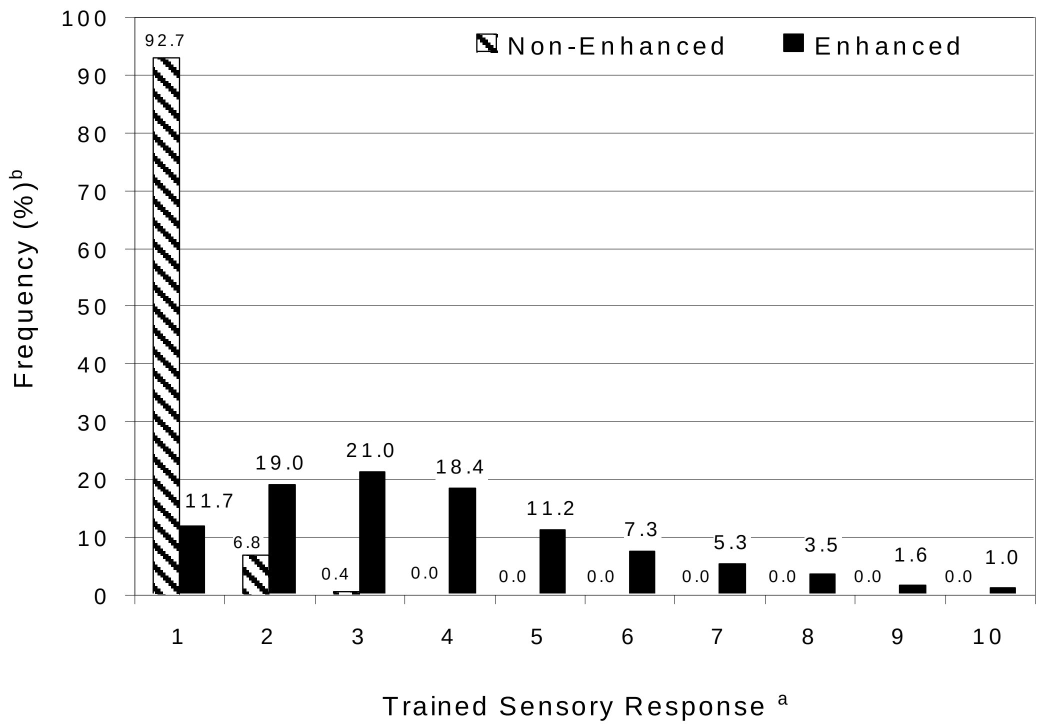


Figure 4 Predicted mean trained sensory responses for Level of Saltiness for non-enhanced and enhanced chops across Warner Bratzler Shear Force levels (N).



a Trained Sensory Ratings, 10-Point Scale; 1 = None, 10 = Intense

b Frequency presented as a percent based on total number of enhancedand non-enhanced chops, respectively.

Figure 5. Frequency of trained sensory ratings for level of saltiness for non-enhanced and enhanced pork chops.

Trained Sensory – Enhanced and Non-Enhanced Conclusions

Results of the present study indicate that enhancement improves trained sensory assessments of tenderness, juiciness and chewiness across a typical range of cooked temperatures and a characteristic range of fresh pork color, intramuscular fat, and loin pH as well as for across a wide range of shear force measured on cooked chops when compared directly with non-enhanced pork representing the same range of attributes. Lower end-point cooked temperatures resulted in improved sensory tenderness and juiciness ratings, but had little to no influence on chewiness, pork fat flavor, pork lean flavor, or saltiness, suggesting that under the conditions evaluated in the present study that lowering end-point cooking temperature recommendations may improve eating qualities of pork. In addition, results indicate that Warner Bratzler shear force levels played the largest impact on sensory perception of pork tenderness, chewiness and juiciness with small incremental increases in WBS resulting in large, unfavorable changes in sensory ratings for both non-enhanced and enhanced pork chops and suggesting that WBS, measured on the cooked chop, is a critical factor influencing overall pork palatability. Within the present study, loin pH was the only fresh pork quality attribute that had an appreciable relationship with WBS and trained panel tenderness scores and might therefore serve as an indicator trait for assessing pork tenderness. Loin intramuscular fat and objective Minolta L* color were significantly associated with most trained sensory attributes measured, although their impact on sensory ratings were most likely of value only when comparing the ends of range evaluated rather then differentiating small increments within each characteristic’s range. A lack of significant interactions among quality traits in relation to sensory response attributes suggests that optimal combinations of fresh quality attributes combined with proper cooking temperature will improve the eating quality of both enhanced and non-enhanced pork.

Appendix

Trained Sensory Ballot

PORK LOIN Sample _______________

Name ______________________

Date ______________________

Evaluate the sample and indicate the intensity of each attribute on the 10-point category scales.

JUICINESS

___	___	___	___	___	___	___	___	___	___
Dry	2	3	4	5	6	7	8	9	Juicy

TENDERNESS

___	___	___	___	___	___	___	___	___	___
Tough	2	3	4	5	6	7	8	9	Tender

CHEWINESS

___	___	___	___	___	___	___	___	___	___
Not Chewy	2	3	4	5	6	7	8	9	Very chewy

COOKED PORK LEAN FLAVOR

___	___	___	___	___	___	___	___	___	___
None	2	3	4	5	6	7	8	9	Intense

COOKED PORK FAT FLAVOR

___	___	___	___	___	___	___	___	___	___
None	2	3	4	5	6	7	8	9	Intense

OFF-FLAVOR

___	___	___	___	___	___	___	___	___	___
None	2	3	4	5	6	7	8	9	Intense

SALTINESS

___	___	___	___	___	___	___	___	___	___
None	2	3	4	5	6	7	8	9	Intense

A	Acid	CH	Chemical	M	Metallic	SB	Serumy/bloody
B	Bitter	CW	Cowy	N	Nutty	SD	Soured
BR	Browned	F	Fish-like	P	Putrid	SO	Sour
C	Cardboard	L	Liver	SA	Salty	SW	Sweet

Consumer Recruitment Screener & Questionnaire

Beacon Associates
OSU Research Recruit-Pork

Respondent Name: ______________________________
Interview Time: _____________
Address: ____

Home Phone: ____________________

Work Phone: __________________________

General Specs Per City:

- Recruit xxx respondents per city, for 760 to show
- 38 groups of 20 resps to show (recruit xx for 20 to show)
- Each respondent to participate in a 1 hour taste test.
- Adults Ages 24-49 yrs old
- 60% women & 40% men
- All must be regular consumers of Pork = (total pork at least 3x in last month= fresh pork at least 2x in last month and other pork at least 1x in past month)
- Must have children under the age of 18 living in the household
- HH Income: $30k+
- Ethnicity as it falls
- No exclusions of/aversions to pork
- No sensitive occupations
- No past participation within 3 months

ASK TO SPEAK TO MALE OR FEMALE HEAD OF HOUSEHOLD.
Hello, my name is _________, from _________, an independent research company. We are conducting a marketing research study and would like to include your opinions. Please be assured we are not selling anything and the information gathered will remain confidential and be used for research purposes only. If you are interested in participating and qualify for our study, we will ask you to take part in a 1 hour session on (DATE/S). May I continue? ***(If not, terminate.)***
I am going to ask you a series of questions to see if you qualify, you may refuse to answer or terminate this interview at any time.

1. Research companies are particularly interested in knowing if people have some relationship with or knowledge about certain occupations. Think about the job(s) and occupations you and members of your family, close friends and relatives hold. Do any have jobs that are in the following types of companies or have related job titles: ***(Read options slowly.)***

* Food production or manufacturing plant .... ( )
* At a restaurant, hotel, or bar as a chef or cook .... ( )
* Marketing or market research .... ( )
* Advertising agency, graphic design or public relations .... ( )
* Television, radio, magazine, or newspaper.. ( )
* Direct mail or promotional agency.. ( )

If yes to any, terminate.

2. Are you employed: ***(Read list.)***

Full-time ( ) Continue to Q3
Part-time ( ) Continue to Q3
Retired ( ) SKIP to Q4
Not employed by choice ( ) SKIP to Q4
Unemployed ( ) SKIP to Q4 (Limit to 2 per group)

3. a) What is your occupation?____
b) What industry do you work in? ____

Must NOT be employed in any industry mentioned in Q1.

4. Have you participated in a market research discussion, taste test, or a one-on-one interview about products or services in the last three months?

( ) Yes **Terminate**
( ) No

5. Please tell me your age: ***(Write EXACT age on line below.)***

_____________ ***Must be 24-49 years old to continue. Check quotas***
Record age-- Hold those who are close to but outside of the age range

Record Gender from voice:

Male ( ) SEE QUOTAS
Female ( ) SEE QUOTAS

Recruit 60% women & 40% men

6. When I list products below, please indicate the number of times you have eaten the product in the past month.

	1x in last month	2x in last month	3x in last month	4+ in last month
Pork Chops*				
Pork Roast*				
Pork Ribs*				
Bacon				
Pork Tenderloin*				
Ham				
Pork Sausage				

Must say any fresh pork* at least 2x in the last month, and any other pork products at least 1x in the past month to qualify.

7. When I list the products below, please indicate the number of times you have eaten these products in the past month.

	1x in last month	2x in last month	3x in last month	4+ in last month
Beef Roast				
Ground Beef				
Steak				
Beef Ribs				
Chicken Breast				
Chicken Wings				
Whole Chicken				

Record all answers- no terminates.

8. Which of the following ranges best describes your total annual household income?

Under $30,000 ( ) ***Terminate***
$30,000-$44,999 ( ) *Continue*
$45,000-$59,999 ( ) *Continue*
$60,000-$79,999 ( ) *Continue*
$80,000-$99,999 ( ) *Continue*
$100,000+ ( ) *Continue*
Record, must be $30,000 or higher.

9. We would like to make sure that we have properly represented each ethnic group. What is your race or ethnic origin?

( ) Hispanic
( ) Caucasian
( ) African American
( ) Asian American
( ) Native American
( ) Other
Record

10. How many people live in your household? ____________________
(**Record exact number**)

11. How many people under the age of 18 live in your household? __________
(**Record exact number**)

Must have at least one adult and at least one child under the age of 18 living in household to qualify.

<u>(cont)</u>

INVITE:

Thank you. I would like to invite you to participate in a research study. Our study will take 1 hour. In the session, you will be asked to taste, rate and give your opinion of several different pork products. You will be paid: $40 after the group, for your participation if you agree to participate. The data collected in the study will be analyzed by research personnel from The Ohio State University and Texas A&M University. Your identity will remain confidential throughout the study. Would you be interested in participating?

Yes ( ) *Continue*
No ( ) ***Terminate***

In our study, we will be tasting samples of pork. Would you be willing to taste different pork products?

Yes ( )*Continue*
No ( )***Terminate***

Must be willing to taste pork products to qualify.

Our session will be held on (__Date_____) At (___Time____). Are you available then?

Yes ( ) *Continue*
No ( ) ***Terminate***

A postcard reminder will be mailed to you confirming the exact location of your interview, the date, start time, end time, and contact name and number for your interview. We will also call you with a reminder the day/night before your interview. If you have questions regarding this research trial please contact XXXXXX at XXXXXX at the following telephone number XXX-XXX-XXXX. Again, that number is XXX-XXX-XXXX.

Thank you for volunteering to participate in this study. Can I please confirm your contact information? **FILL IN THE PERSONAL INFORMATION ON THE FIRST PAGE BEFORE HANGING UP.**

Please remember to bring your reading glasses, if you use them, as you will be asked to complete written questionnaires as part of the research. Also, please plan to arrive at the interview location 15 minutes early so that we can start on time. Do you have any questions? Thank you.

Institutional Review Board – Consumer Consent Form

Protocol # ________________

CONSENT FOR PARTICIPATION IN RESEARCH

I consent to participating in research conducted through Beacon Associates in association with Precision Research entitled: Pork Evaluation Study.

Beacon Associates and his/her authorized representative have explained that I will be asked to taste, rate and give my opinion of several different pork products, they have outlined the procedures to be followed, and provided information regarding the expected duration of my participation.

I acknowledge that I have been provided contact information to obtain additional information regarding the study and that any questions I have raised have been answered to my full satisfaction. In addition, I recognize that the response data collected, after removal of all personal identifiers to maintain my confidentiality, will be analyzed by investigators at The Ohio State University and Texas A&M University. Furthermore, I understand that I am free to withdraw consent at any time and to discontinue participation in the study without prejudice to me.

Finally, I acknowledge that I have read and fully understand the consent form. I sign it freely and voluntarily. A copy has been given to me.

Date: ________________________________

Signed: ________________________________
(Participant)

Signed: Steven J. Moeller
(Principal Investigator or his/her authorized representative)

Signed: ________________________________
(Person authorized to consent for participant, if required)

Witness: ________________________________

Consumer Recruitment Questionnaire Responses

Table 1A. National Pork Board Consumer Study: Consumer demographics for gender by city.

City	Male	Female	Total
Chicago	453 21.84%	292 14.08%	745 35.92%
Philadelphia	377 18.18%	212 10.22%	589 28.40%
Sacramento	450 21.70%	290 13.98%	740 35.68%
Total	1280 61.72%	794 38.28%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete.

Table 2A. National Pork Board Consumer Study: Consumer demographics for income distribution.

City	$30-44k	$45-59k	$60-79k	$80-99k	$100+k	N/A	Total
Chicago	104 5.01%	165 7.96%	188 9.06%	151 7.28%	137 6.61%	0 0.00%	745 35.92%
Philadelphia	54 2.60%	115 5.54%	167 8.05%	133 6.41%	120 5.79%	0 0.00%	589 28.40%
Sacramento	218 10.51%	172 8.29%	173 8.34%	80 3.86%	94 4.53%	3 0.14%	740 35.68%
Total	376 18.13%	452 21.79%	528 25.46%	364 17.55%	351 16.92%	3 0.14%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 3. National Pork Board Consumer Study: Consumer demographics for ethnicity.

City	African American	Asian American	Caucasian	Hispanic American	Native American	Other	Total
Chicago	70 3.38%	7 0.34%	590 28.45%	62 2.99%	4 0.19%	12 0.58%	745 35.92%
Philadelphia	48 2.31%	3 0.14%	527 25.41%	8 0.39%	0 0.00%	3 0.14%	589 28.40%
Sacramento	120 5.79%	50 2.41%	418 20.15%	115 5.54%	6 0.29%	27 1.30%	740 35.68%
Total	238 11.48%	60 2.89%	1535 74.01%	185 8.92%	10 0.48%	42 2.03%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 3A. National Pork Board Consumer Study: Consumer demographics for number of persons in the household.

City	1	2	3	4	5	6	7	8	9	10	Total
Chicago	0 0.00%	34 1.64%	172 8.30%	321 15.49%	151 7.29%	53 2.56%	8 0.39%	2 0.10%	2 0.10%	1 0.05%	744 35.91%
Philadelphia	0 0.00%	27 1.30%	136 6.56%	241 11.63%	134 6.47%	37 1.79%	9 0.43%	4 0.19%	1 0.05%	0 0.00%	589 28.43%
Sacramento	1 0.05%	135 6.52%	283 13.66%	217 10.47	68 3.28%	20 0.97%	11 0.53%	3 0.14%	1 0.05%	0 0.00%	739 35.67%
Total	1 0.05%	196 9.46%	591 28.52%	779 37.60%	353 17.04%	110 5.31%	28 1.35%	9 0.43%	4 0.19%	1 0.05%	2072 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 4A. National Pork Board Consumer Study: Consumer demographics for number of children in the household.

City	1	2	3	4	5	6	7	8	Total
Chicago	0 0.00%	240 11.58%	333 16.06%	39 1.88%	5 0.24%	0 0.00%	0 0.00%	1 0.05%	745 35.94%
Philadelphia	0 0.00%	218 10.52%	233 11.24%	29 1.40%	4 0.19%	2 0.10%	1 0.05%	0 0.00%	589 28.41%
Sacramento	1 0.05%	449 21.66%	206 9.94%	18 0.87%	7 0.34%	1 0.05%	0 0.00%	0 0.00%	739 35.65%
Total	1 0.05%	907 43.75%	772 37.24%	86 4.15%	16 0.77%	3 0.14%	1 0.05%	1 0.05%	2073 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 5A. National Pork Board Consumer Study: Consumer demographics for frequency of pork chop consumption per month by city.

	Pork Chop Consumption (frequency per month)					
City	0	1	2	3	4	Total
Chicago	44 2.12%	164 7.91%	220 10.61%	129 6.22%	188 9.06%	745 35.92%
Philadelphia	46 2.22%	108 5.21%	205 9.88%	134 6.46%	96 4.63%	589 28.41%
Sacramento	75 3.62%	145 6.99%	272 13.11%	100 4.82%	148 7.14%	739 35.65%
Total	165 7.96%	417 20.11%	697 33.61%	363 17.50%	432 20.83%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 6A. National Pork Board Consumer Study: Consumer demographics for frequency of pork chop consumption per month by number of children in the household.

	Number of Children									
Chops/Month	0	1	2	3	4	5	6	7	8	Total
0	0 0.00%	67 3.23%	61 2.94%	25 1.21%	9 0.43%	3 0.14%	0 0.00%	0 0.00%	0 0.00	165 7.96%
1	0 0.00%	179 8.63%	160 7.72%	64 3.09%	11 .53%	3 .14%	0 0.00%	0 0.00%	0 0.00%	417 20.12%
2	1 .05%	317 15.29%	250 12.06%	90 4.34%	32 1.54%	4 .19%	2 0.10%	0 0.00%	0 0.00%	696 33.57%
3	0 0.00%	166 8.01%	135 6.51%	44 2.12%	15 .72%	1 .05%	0 0.00%	1 .05%	1 .05%	363 17.51%
4	0 0.00%	178 8.59%	166 8.01%	63 3.04%	19 .92%	5 .24%	1 .05%	0 0.00%	0 0.00%	432 20.84%
Total	1 0.05%	907 43.75%	772 37.24%	286 13.80%	86 4.15%	16 .77%	3 .14%	1 .05%	1 .05%	2073 100%

Table 7A. National Pork Board Consumer Study: Consumer demographics for frequency of pork chop consumption per month by number of persons in the household.

	Number in Household										
Chops/ Month	1	2	3	4	5	6	7	8	9	10	Total
0	0 0.00%	15 0.72%	40 1.93%	67 3.23%	29 1.40%	8 0.39%	5 0.24%	1 0.05%	0 0.00%	0 0.00%	165 7.96%
1	0 0.00%	34 1.64%	132 6.37%	148 7.14%	79 3.81%	18 0.87%	6 0.29%	0 0.00%	0 0.00%	0 0.00%	417 20.13%
2	1 0.05%	72 3.47%	191 9.22%	262 12.64%	119 5.74%	37 1.79%	8 0.39%	4 0.19%	1 0.05%	0 0.00%	695 33.54%
3	0 0.00%	42 2.03%	96 4.63%	142 6.85%	53 2.56%	23 1.11%	2 0.10%	2 0.10%	2 0.10%	1 0.05%	363 17.52%
4	0 0.00%	22 1.59%	132 6.37%	160 7.72%	73 3.52%	24 1.16%	7 0.34%	2 0.10%	1 0.05%	0 0.00%	432 20.85
Total	1 0.05%	196 9.46%	591 28.52%	779 37.60%	353 17.04%	110 5.31%	28 1.35%	9 0.43%	4 0.19%	1 0.05%	2072 100%

Table 8A. National Pork Board Consumer Study: Consumer demographics for frequency of pork rib consumption per month.

	Pork Rib Consumption (frequency per month)					
City	0	1	2	3	4	Total
Chicago	140 6.75%	256 12.34%	172 8.29%	82 3.95%	95 4.58%	745 35.92%
Philadelphia	176 8.49%	175 8.44%	152 7.33%	58 2.80%	28 1.35%	589 28.40%
Sacramento	137 6.61%	197 6.99%	224 10.80%	88 4.24%	94 4.53%	740 35.68%
Total	453 21.84%	9.50 20.11%	548 26.42%	228 10.99%	217 10.46%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 9A. National Pork Board Consumer Study: Consumer demographics for frequency of bacon consumption per month.

	Bacon Consumption (frequency per month)					
City	0	1	2	3	4	Total
Chicago	39 1.88%	69 3.33%	111 5.35%	105 5.06%	421 20.30%	745 35.92%
Philadelphia	31 1.49%	54 2.60%	135 6.51%	140 6.75%	229 11.04%	589 28.40%
Sacramento	40 1.93%	68 3.28%	106 5.11%	100 4.82%	426 20.54%	740 35.68%
Total	110 5.30%	191 9.21%	352 16.97%	345 16.63%	1076 51.88%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 10A. National Pork Board Consumer Study: Consumer demographics for frequency of ham consumption per month.

	Ham Consumption (frequency per month)					
City	0	1	2	3	4	Total
Chicago	73 3.52%	97 4.68%	115 5.54%	87 4.19%	373 17.98%	745 35.92%
Philadelphia	51 2.46%	122 5.88%	137 6.61%	111 5.35%	168 8.10%	589 28.40%
Sacramento	74 3.57%	150 7.23%	131 6.32%	96 4.63%	286 13.79%	740 35.68%
Total	198 9.55%	369 17.79%	383 18.47%	294 14.18%	827 39.87%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 11A. National Pork Board Consumer Study: Consumer demographics for frequency of pork sausage consumption per month.

	Pork Sausage Consumption (frequency per month)					
City	0	1	2	3	4	Total
Chicago	186 8.97%	128 6.17%	135 6.51%	90 4.34%	206 9.93%	745 35.92%
Philadelphia	133 6.41%	144 6.94%	147 7.09%	86 4.15%	79 3.81%	589 28.40%
Sacramento	152 7.33%	141 6.80%	171 8.24%	81 3.91%	195 9.40%	740 35.68%
Total	471 22.71%	413 19.91%	453 21.84%	257 12.39%	480 23.14%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 12A. National Pork Board Consumer Study: Consumer demographics for frequency of ground beef consumption per month.

	Ground Beef Consumption (frequency per month)					
City	0	1	2	3	4	Total
Chicago	12 0.58%	19 0.92%	56 2.70%	79 3.81%	579 27.92%	745 35.92%
Philadelphia	13 0.63%	42 2.03%	120 5.79%	129 6.22%	285 13.74%	589 28.40%
Sacramento	30 1.45%	52 2.51%	111 5.35%	117 5.64%	430 20.73%	740 35.68%
Total	55 2.65%	113 5.45%	287 13.84%	325 15.67%	1294 62.39%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 13A. National Pork Board Consumer Study: Consumer demographics for frequency of beef steak consumption per month.

	Beef Steak Consumption (frequency per month)					
City	0	1	2	3	4	Total
Chicago	33 1.59%	93 4.48%	181 8.73%	128 6.17%	310 14.95%	745 35.92%
Philadelphia	66 3.18%	134 6.46%	184 8.87%	103 4.97%	102 4.92%	589 28.40%
Sacramento	67 3.23%	147 7.09%	180 8.68%	117 5.64%	229 11.04%	740 35.68%
Total	166 8.00%	374 18.03%	545 26.28%	348 16.78%	641 30.91%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 14A. National Pork Board Consumer Study: Consumer demographics for frequency of beef rib consumption per month.

	Beef Rib Consumption (frequency per month)					
City	0	1	2	3	4	Total
Chicago	379 18.27%	188 9.06%	86 4.15%	39 1.88%	53 2.56%	745 35.92%
Philadelphia	338 16.30%	124 5.98%	90 4.34%	20 0.96%	17 0.82%	589 28.40%
Sacramento	376 18.13%	200 9.64%	85 4.10%	30 1.45%	49 2.36%	740 35.68%
Total	1093 52.70%	512 24.69%	261 12.58%	89 4.29%	119 5.74%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 15A. National Pork Board Consumer Study: Consumer demographics for frequency of chicken breast consumption per month.

	Chicken Breast Consumption (frequency per month)					
City	0	1	2	3	4	Total
Chicago	11 0.53%	14 0.68%	50 2.41%	80 3.86%	590 28.45%	745 35.92%
Philadelphia	17 0.82%	20 0.96%	81 3.91%	93 4.48%	378 18.23%	589 28.40%
Sacramento	23 1.11%	39 1.88%	77 3.71%	87 4.19%	514 24.78%	740 35.68%
Total	51 2.46%	73 3.52%	208 10.03%	260 12.54%	1482 71.46%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 16A. National Pork Board Consumer Study: Consumer demographics for frequency of chicken wing consumption per month.

	Chicken Wing Consumption (frequency per month)					
City	0	1	2	3	4	Total
Chicago	192 9.26%	179 8.63%	119 5.74%	77 3.71%	178 8.58%	745 35.92%
Philadelphia	182 8.78%	133 6.41%	135 6.51%	57 2.75%	82 3.95%	589 28.40%
Sacramento	240 11.57%	167 8.05%	122 5.88%	50 2.41%	161 7.76%	740 35.68%
Total	614 29.60%	479 23.10%	376 18.13%	184 8.87%	421 20.30%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Table 17A. National Pork Board Consumer Study: Consumer demographics for frequency of whole chicken consumption per month.

	Whole Chicken Consumption (frequency per month)					
City	0	1	2	3	4	Total
Chicago	196 9.45%	217 10.46%	177 8.53%	64 3.09%	91 4.39%	745 35.92%
Philadelphia	129 6.22%	206 9.93%	136 6.56%	53 2.56%	65 3.13%	589 28.40%
Sacramento	204 9.84%	255 12.30%	136 6.56%	47 2.27%	98 4.73%	740 35.68%
Total	529 25.51%	678 32.69%	449 21.65%	164 7.91%	254 12.25%	2074 100%

[a] Data from ~161 respondents in Philadelphia not complete

Consumer Ballot

Participant Number ______ **Sample Number _______**
Group Time 8:30 p.m. **Date ___________**

1. Indicate by placing a mark in the box your **OVERALL LIKE/DISLIKE** of the meat sample.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Dislike Extremely — Like Extremely

2. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **JUICINESS**.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Dislike Extremely — Like Extremely

3. Indicate by placing a mark in the box how you feel about the **LEVEL** of **JUICINESS**.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Extremely Dry — Extremely Juicy

4. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **TENDERNESS**.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Dislike Extremely — Like Extremely

5. Indicate by placing a mark in the box how you feel about the **LEVEL** of **TENDERNESS**.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Extremely Tough — Extremely Tender

6. Indicate by placing a mark in the box your **LIKE/DISLIKE** for the **FLAVOR**.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Dislike Extremely — Like Extremely

7. Indicate by placing a mark in the box how you feel about the **LEVEL** of **FLAVOR**.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐
Extremely Bland or No Flavor — Extremely Flavorful

8. How likely would you be to **PURCHASE** this sample if it were available at a reasonable price in your area? Please circle one of the choices below.

Definitely Would Buy

Probably Would Buy

May or May Not Buy

Probably Would Not Buy

Definitely Would Not Buy

Post-Sensory Consumer Demographic Questionnaire

Consumer Number _______ **1 Group Time _______________**
Date ______________________

1. On average, how many meals do you eat away from home (at restaurants) each month? (Place an X on one line below.)
   _____ 15 meals or more
   _____ 10-14 meals
   _____ 4-9 meals
   _____ 1-3 meals
   _____ Never

2. Who in your household typically does a majority of the grocery shopping? (Place an X on one line below.)
   _____ Self
   _____ Spouse
   _____ Other

3. When grocery shopping, where do you typically shop? (Place an X on one line below.)
   _____ Grocery chain (i.e., Genuardi's, Giant, Super Fresh, Acme, Wegmans)
   _____ Small or specialty grocer (i.e., Whole Foods, Hennings)
   _____ Discount or warehouse store (i.e., Sam's Club, CostCo, BJsp)
   _____ On-line/Web
   _____ Other: (Please describe: ________________________________)

4. At what store do you most often purchase meat products? (Indicate a store or chain name on the line below.)
   ____

5. Who is the main meal preparer in your home? (Place an X on one line below.)
   _____ Self
   _____ Spouse
   _____ Kids
   _____ Other

6. How often does your family prepare and eat dinner meals at home in an average month? (Place an X on one line below.)
   _____ 15 meals or more
   _____ 10-14 meals
   _____ 4-9 meals
   _____ 1-3 meals
   _____ Never

7. On average, how long does it take to prepare a dinner meal in your home? (Place an X on one line below.)
_____ More than 1 hour
_____ 30 minutes to 1 hour
_____ 15 to 30 minutes
_____ Less than 15 minutes

8. How many frozen entrees or heat-n-serve store-purchased meals do you consume in an average month? (Place an “X” on one line below.)
_____ 15 meals or more
_____ 10-14 meals
_____ 4-9 meals
_____ 1-3 meals
_____ Never

9. How important are each of the following attributes to you when deciding which type of meat or poultry to purchase for you or your family? (Place a number on each line below using a range from 1 to 10, where 10 means EXTREMELY IMPORTANT and 1 means NOT AT ALL IMPORTANT.):
_____ Can be prepared in a variety of ways
_____ A food that makes meals interesting
_____ A family favorite
_____ A healthful food
_____ A food that breaks up the monotony of weekly meals
_____ Is great tasting
_____ A good value for the money

10. Indicate your overall favorability for the following types of meat. (Place a number on each line below using range from 1 to 10, where 10 means VERY FAVORABLE and 1 means UNFAVORABLE.)
_____ Chicken
_____ Beef
_____ Pork
_____ Seafood

11. How interested would you be in a frozen meal product at a grocer store that would feature a pork entrée (i.e., a pork tenderloin dish, shredded pork dish)? (Place an “X” on one line below.)
_____ **Definitely Would Buy**
_____ Probably Would Buy
_____ May or May Not Buy
_____ Probably Would Not Buy
_____ Definitely Would Not Buy

THANK YOU.

Post-Sensory Consumer Demographic Questionnaire Responses

Table 1B. National Pork Board Consumer Study Demographics: Question: On average, how many meals do you eat away from home (at restaurants) each month?

	Frequency	Percent
Never	4	0.18
1 to 3 meals	537	24.11
4 to 9 meals	1018	45.71
10 to 14 meals	427	19.17
15 or more meals	241	10.82

Table 2B. National Pork Board Consumer Study Demographics: Question: Who in your household typically does a majority of the grocery shopping?

	Frequency	Percent
Self	1700	76.44
Spouse	481	21.63
Other	3	1.93

Table 3B. National Pork Board Consumer Study Demographics: Question: When grocery shopping, where do you typically shop?

	Frequency	Percent
Grocery chain	1778	79.98
Small or specialty grocer	178	8.01
Discount or warehouse store	198	8.91
Online or web	3	0.13
Other	66	2.97

Table 4B (Chicago). National Pork Board Consumer Study Demographics: Question: At what store do you most often purchase meat products?

Chicago Meat Purchase Stores	**Number**	**Percent**
Jewel	341	46.84
Dominicks	87	11.95
Costco	48	6.59
Sams	47	6.46
Butera	24	3.30
Meijer	23	3.16
Caputo	14	1.92
Whole Foods	13	1.79
Aldi	11	1.51
Super Low	11	1.51
Food 4 Less	10	1.37
Cub	9	1.24
Vali Produce	9	1.24
Tony Finer Foods	8	1.10
Trader Joes	6	0.82
Happy Food	5	0.69
Joes Meat Market	4	0.55
Super Target	4	0.55
A&G	3	0.41
Cermak	3	0.41
EuroFresh	3	0.41
Fresh Market	3	0.41
Ultra Foods	3	0.41
Certified Grocer	2	0.27
Edmar Foods	2	0.27
Jimenez	2	0.27
Market Day	2	0.27
Moo & Oink	2	0.27
Produce World	2	0.27
Shop ‘N Save	2	0.27
Wheaton Meats	2	0.27
Berwun Fruit Market, Bitcher, Bobaks, Chipains, DelRay Foods, Devon Market, Elain Fresh Fruit Market, Fair Play, Fiesta Market, Guero, Harvest Foods, Montrose Deli, Mr. Z, Nottoci, Omaha Steaks, Pete’s Market, Save Less, Schmeissers, Sun View, Sunset Foods, Treasure Island, Wally’s Market, Woodman’s	All Frequency’s 1	

Table 4B (Philadelphia). National Pork Board Consumer Study Demographics: Question: At what store do you most often purchase meat products?

Philadelphia Meat Purchase Stores	Number	Percent
Giant	219	29.67
ACME	120	16.26
Costco	69	9.35
Genuardi's	65	8.81
Landis	53	7.18
Shop Rite	47	6.37
Redners	23	3.12
Super Fresh	21	2.85
Hennings	19	2.57
Wegman's	14	1.90
Lansdale	13	1.76
Sam's	11	1.49
Pathmark	10	1.36
Weis	10	1.36
BJ's	9	1.22
Whole Foods	5	0.68
Aldi	3	0.41
Butcher	3	0.41
Colonial	3	0.41
Fresh Market	2	0.27
Haring Bros.	2	0.27
Shady Maple	2	0.27
Shop 'N Bag	2	0.27
Bedner's	1	0.14
Boyers	1	0.14
Davis Food Co-Op	1	0.14
Dream Dinners	1	0.14
Farm Market	1	0.14
IGA	1	0.14
Joe's Meat Market	1	0.14
King's	1	0.14
Market Day	1	0.14
Q-Market	1	0.14
Thriftway	1	0.14
Wal-Mart	1	0.14
Wilson	1	0.14

Table 4B (Sacramento). National Pork Board Consumer Study Demographics: Question: At what store do you most often purchase meat products?

Sacramento Meat Purchase Store	**Number**	**Percent**
Safeway	153	20.96
Costco	117	16.03
Raley's	108	14.79
BelAir	88	12.05
Albertson's	75	10.27
Winco	72	9.86
Food Co.	23	3.15
Sam's	23	3.15
Trader Joe's	18	2.47
Nugget	13	1.78
Wal-Mart	11	1.51
Corti Brothers	3	0.41
Military Commisary	3	0.41
Taylor's	3	0.41
Whole Foods	3	0.41
Food 4 Less	2	0.27
Harvest Foods	2	0.27
Smart & Final	2	0.27
Vic's	2	0.27
Butchers Roseville Meat Co.	1	0.14
Comptons Family Market	1	0.14
Curtis Park Market	1	0.14
Davis Food Co-Op	1	0.14
Mad Butcher	1	0.14
Natural Foods Co-Op	1	0.14
Nobb Hill	1	0.14
Omaha Steaks	1	0.14
QVC	1	0.14

Table 5B. National Pork Board Consumer Study Demographics: Question: Who is the main meal preparer in your home?

	Frequency	Percent
Self	1617	72.71
Spouse	559	25.13
Kids	3	0.13
Other	45	2.02

Table 6B. National Pork Board Consumer Study Demographics: Question: How often does your family prepare and eat dinner meals at home in an average month?

	Frequency	Percent
Never	5	0.22
1 to 3 meals	8	0.36
4 to 9 meals	95	4.27
10 to 14 meals	379	17.03
15 or more meals	1739	78.12

Table 7B. National Pork Board Consumer Study Demographics: Question: On average, how long does it take to prepare a dinner meal in your home?

	Frequency	Percent
< 15 Minutes	3	0.14
15 to 30 Minutes	261	11.82
30 Minutes to an Hour	1673	75.74
> 1 hour	270	12.22

Table 8B. National Pork Board Consumer Study Demographics: Question: How many frozen entrees or heat-n-serve store-purchased meals do you consume in an average month?

	Frequency	Percent
Never	207	9.37
1 to 3 meals	805	36.44
4 to 9 meals	852	38.57
10 to 14 meals	261	11.82
15 or more meals	84	3.80

Table 9B. National Pork Board Consumer Study Demographics: Question: How important are each of the following attributes to you when deciding which type of meat or poultry to purchase for you or your family? (Range 1 to 10, where 10 = EXTREMELY IMPORTANT and 1 = NOT AT ALL IMPORTANT.):

	Attribute, %						
Importance	**Family Favorite**	**Value**	**Variety**	**Taste**	**Reduce Monotony**	**Interesting**	**Healthful**
1 = Not Important	1.94	1.90	3.20	2.13	4.32	5.01	2.50
2	1.43	1.76	2.59	0.97	3.81	4.36	1.39
3	0.97	2.45	3.01	0.74	3.99	4.69	1.48
4	1.62	2.59	2.41	0.69	3.85	4.55	2.08
5	4.95	6.57	10.01	1.39	14.90	14.48	6.85
6	5.04	5.41	6.49	1.53	10.07	11.04	5.00
7	10.55	10.37	12.37	4.49	17.77	16.19	12.12
8	22.21	19.25	20.39	14.13	19.91	18.14	21.14
9	15.92	13.05	11.86	18.06	8.82	7.94	15.40
10= Extremely Important	**35.35**	**36.65**	27.66	**55.86**	12.58	13.60	**32.05**
Mean Rating	**8.18**	**7.99**	**7.49**	**8.91**	**6.63**	**6.51**	**7.95**

Table 10B. National Pork Board Consumer Study Demographics: Question: Indicate your overall favorability for the following types of meat. (Range 1 to 10, where 10 = VERY FAVORABLE and 1 = UNFAVORABLE.)

		Pork	Beef	Chicken	Seafood
Favorability	1 - Unfavorable	1.52 %	2.95 %	2.43 %	10.34 %
	2	1.70 %	2.03 %	1.70 %	4.61 %
	3	2.62 %	2.58 %	1.06 %	4.85 %
	4	2.16 %	3.13 %	1.19 %	5.08 %
	5	4.82 %	6.95 %	4.00 %	9.88 %
	6	5.70 %	5.39 %	3.77 %	4.94 %
	7	14.79 %	10.50 %	8.96 %	10.75 %
	8	26.73 %	20.07 %	18.83 %	13.75 %
	9	15.07 %	14.36 %	16.03 %	8.81 %
	10 = Very Favorable	24.90 %	32.04 %	**42.03 %**	27.00 %
	Mean Rating	**7.82**	**7.78**	**8.34**	**6.68**

Table 11. National Pork Board Consumer Study Demographics: Question: How interested would you be in a frozen meal product at a grocer store that would feature a pork entrée (i.e., a pork tenderloin dish, shredded pork dish)?

	Frequency	Percent
Definitely would buy	66	3.00
Probably would buy	159	7.22
May or may not buy	659	29.94
Probably would not buy	844	38.35
Definitely would not buy	473	21.49

Research Cited

Aberle, E. D., J. C. Forrest, D. E. Gerrard, and E. W. Mills. 2001. Principles of meat science. (4th ed.) Dubuque, IA: Kendall/Hunt Publishing Company.

Baublits, R. T., J.-F. Meullenet, J. T. Sawyer, J. M. Mehaffey, and A. Saha. 2006. Pump rate and cooked temperature effects on pork loin instrumental, sensory descriptive and consumer-rated characteristics. Meat Science. 72:741-750.

Bouton, P. E., and P. V. Harris. 1972. The effect of cooking temperature and time on some mechanical properties of meat. Journal of Food Science. 37; 140-144.

Brewer, M. S., L. G. Zhu, F. K. McKeith. 2001. Marbling effects on quality characteristics of pork loin chops: consumer purchase intent, visual and sensory characteristics. Meat Science. 59: 153 – 163

Brewer, M. S., J. Novakofski, and K. Freise. 2006. Instrumental evaluation of pH effects on ability of pork chops to bloom. Meat Science. 72; 596-602.

Christensen, M., P.P. Purslow, L.M. Larsen. 2000. The effect of cooking temperatures on mechanical properties of whole meat, single muscle fibers and perimysial connective tissue. Meat Science, 55, 301.

Davis, G. W., G. C. Smith, Z. L. Carpenter, and H. R. Cross. 1975. Relationship of quality indicators to palatability attributes of pork loins. Journal of Animal Science. 41; 1305.

DeVol, D. L., F. K. McKeith, P.J. Bechtel, J. Novakoski, R. D. Shanks, and T. R. Carr. 1988. Variation in composition and palatability traits and relationship between muscle characteristics and palatability in a random sample of pork carcasses. Journal of Animal Science. 66:385-395

Fernandez, X., G. Monin, A. Talmont, J. Mourot, and B. Lebret. 1999. Influence of intramuscular fat content on the quality of pig meat – 1. Composition of the lipid fraction and sensory characteristics of the m. longissimus lumborum. Meat Science, 53: 59.

Fortin, A., W. M. Robertson, A. K. W. Tong, 2005. The eating quality of Canadian pork and its relationship with intramuscular fat. Meat Science 69:297-305

Gardner, M., E. Huff-Lonergan, and S. M. Lonergan. 2005. Prediction of fresh pork quality using indicators of protein degradation and calpain activation. 51st International Congress of Meat Science and Technology, 51; 1428-1434. American Meat Science Association, Baltimore, MD.

Henckel, P., A. Karlsson, N. Oksbjerg, and J. S. Petersen. 2000. Control of postmortem pH decrease in pig muscle: experimental design and testing of animal models. Meat Science. 55; 131-138.

Heymann, H., H. B. Hedrick, M. A. Karrasch, M. K. Eggeman, and M. R. Ellersieck. 1990. Sensory and chemical characteristics of fresh pork roasts cooked to different endpoint temperatures. Journal of Food Science. 55; 613.

Hodgson, R. R., G. W. Davis, G. C. Smith, J. W. Savell and H. R. Cross. 1991 Relationship between pork loin palatability traits and physical characteristics of cooked shops. Journal of Animal Science. 69:4858-4865

Huff-Lonergan, E., T. J. Baas, M. Malek, J. C. Dekkers, K. Prusa, and M. F. Rothschild. 2002. Correlations among selected pork quality traits. Journal of Animal Science. 80; 617-627.

Keeton, T. K. 1983. Effects of fat and NaCl/Phopshate levels on the chemical and sensory properties of pork patties. Journal of Food Science, 48; 878-881 885.

Lonergan, S. M., and K. J. Prusa. 2002. Sensory and instrumental analysis of textural parameters of pork. PP. 33-38 in Reciprocal Meat Conference: Pork Quality Measurement Systems. American Meat Science Association, Savoy, IL.

Lonergan, S. M., K. J. Stalder, E. Huff-Lonergan, T. J. Knight, R. N. Goodwin, K. J. Prusa, and D. C. Beitz. 2007. Influence of lipid content on pork sensory quality within pH classification. Journal of Animal Science. 85; 1074-1079.

Lorenzen, C. L., R. K. Miller, J. F. Taylor, T. R. Neely, J. D. Tatum, J. W. Wise, M. J. Buyck, J. O. Reagan, and J. W. Savell. 2003. Beef consumer satisfaction: Trained sensory panel ratings and Warner-Bratzler shear force values. Journal of Animal Science 81: 143-149.

Norman, J. L., E. P. Berg, H. Heymann, and C. L. Lorensen. 2003. Pork loin color relative to sensory and instrumental tenderness and consumer acceptance. Meat Science 64:927-933.

Platter, W. J., J. D. Tatum, K. E. Belk, P. L. Chapman, J. A. Scanga, and G. C. Smith. 2003. Relationship of consumer sensory ratings, marbling score, and shear force value to consumer acceptance of beef strip loin steaks. Journal of Animal Science. 81: 2741-2750.

Prestat, C., J. Jensen, F. K. McKeith, M. S. Brewer. 2002. Cooking method and endpoint temperature effects on sensory and color characteristics of pumped pork loin chops. Meat Science, 60; 395-400.

Renk, B. Z., R. G. Kauffman, and D. M. Schaefer. 1985. Effect of temperature and method of cookery on the retention of intramuscular lipid in beef and pork. Journal of Animal Science. 61; 876-881.

Rincker, P. J., J. Killefer, M. Ellis, M. S. Brewer, and F. K. McKeith. 2008. Intramuscular fat content has little influence on the eating quality of fresh pork loin chops. J Anim. Sci. 86: 730-737.

Simmons, S. L., T. R. Carr, and F. K. McKeith. 1985. Effects of Internal Temperature and thickness on palatability of pork loin chops.

Sheard, P. R., G. R. Nute, R. I. Richardson, A. Perry, and A. A. Taylor. 1999. Injection of water and polyphosphate into pork to improve juiciness and tenderness after cooking. Meat Science. 51:371-376.

Sheard, P. R. and A. Tali. 2004. Injection of salt, tripolyphosphate and bicarbonate marinade solutions to improve the yield and tenderness of cooked pork loin. Meat Science. 68:305-311.

Torley, P. J., B. R. D'Arcy, and G. R. Trout. 2000.The effect of ionic strength, polyphosphate type, pH, cooking temperature and preblending on the functional properties of normal and pale, soft, exudative (PSE) pork. Meat Science. 55:451-462.

Van Laack, R. L. J. M., S. G. Stevens, and K. J. Stalder. 2001. The influence of ultimate pH and intramuscular fat content on pork tenderness and tenderization. Journal of Animal Science. 79; 392-397.

Vote, D. J., W. J. Platter, J. D. Tatum, G. R. Schmidt, K. E. Belk, G. C. Smith. 2000. Injection of beef strip loins with solutions containing sodium tripolyphosphate, sodium lactate, and sodium chloride to

Wood, J. D., G. R. Nute, G. A. J. Fursey, and A. Cuthbertson. 1995. The effect of cooking conditions on the eating quality of pork. Meat Science. 40; 127-135.

Wood, J. D., M. Enser, A. V. Fisher, G. R. Nute, R. I. Richardson, and P. R. Sheard. 1999. Manipulating meat quality and composition. In Proceedings of the Nutrition Society, University of Surrey. 58; 363-370.