RESEARCHREPORT

PORK QUALITY

Title: Relationships Between Loin Color, Chop Thickness, Cooking Method, Water-Holding Capacity and Tenderness For Pork Cooked To 62.8°C, **NPB #18-140**

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Industry Summary: Multiple consumer and marketing studies showed that consumers over cooked pork. With over cooking, pork is drier, tougher and not as flavorful. In the extensive consumer study conducted in 2006 to 2007, consumers evaluated pork cooked to four internal temperatures (145, 155, 165 and 175°F). In that study, consumers responded positively to pork loin chops cooked to 145°F. The National Pork Board showed that there was essentially no food safety risk in eating pork cooked to 145°F and the USDA changed the minimal cooked temperature endpoint for pork to 145°F. However, how tenderness and water holding capacity is affected in pork chops and roasts differing in thickness and color score cooked to 145°F was unknown. The objective of this study was to understand the effect of pork loin color (National Pork Board Color Quality Standards 2 and 4) on water holding capacity, chop thickness or roast size, chop and roast type, and cook method on pork cooked to 145°F. Cook time, cook yield and Warner-Bratzler shear force were evaluated. Cooking method and chop thickness dramatically affected cook yield and the time to reach 145°F internal degree of doneness. A common theme throughout for pork chops was as thickness increased, cook time increased and cook yield decreased. Baking pork chops or roasts had the longest cooking times and tended to have the lowest cook yields. Pan sautéing and pan frying had shorter cook times that resulted in higher cook yields and acceptable tenderness values. The blade and boneless chops from loin color score 4 were more tender than comparable chops from loin color score 2, but the opposite was reported for bone-in loin chops. Chop thickness had a minor effect on cook measurements, tenderness and color for blade and bone-in chops, but chop thickness for boneless chops impacted these parameters to a greater extent. Thin boneless loin chops were tougher than thicker boneless loin chops. Although pork that was baked had the longest cook time, baked bone-in and boneless chops were tender. Grilled pork chops and roasts had the lowest cook yield. Overall, this study showed that raw loin color impacted the raw color, pH and drip loss of pork. In addition, in blade, bone-in or boneless pork chops and roasts from these loins, cooking method and chop thickness impacted cook yield, cook time, cooked color, and tenderness.
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Scientific Abstract: Consumer research has consistently shown that consumers over-cook pork creating a subpar eating experience. Understanding the relationship between loin color, cut thickness, cooking method, water-holding capacity and tenderness from chops and roasts cooked to 62.8°C is crucial. Twenty pork boneless chops, blade chops, bone-in chops, tenderloin roast and boneless loin roasts from color score 2 and 4 (National Pork Board color score cards, Des Moines, IA) pork loins in the blade-end lean surface. Prior to cooking, drip loss, pH and raw color were determined. Chops and roasts were then cooked to 62.8°C either by baking, grilling, pan frying, or pan-sautéing. Cook yield, cook time, tenderness assessed by Warner-Bratzler shear force, and cook color were measured and recorded. Cooking method and chop thickness affected ($P < 0.05$) cook yield and cook time. Baked chops had the longest cooking times and pan-sautéd chops had the highest cook yields ($P < 0.05$). Grilled chops had the highest ($P < 0.05$) cook loss. The blade and boneless chops from color score 4 loins were more tender than the same chops from color score 2 loins. However, for bone-in chops, the inverse was reported ($P < 0.05$). Thickness had minimal effect on Warner-Bratzler shear force values ($P>0.05$). Although bone-in and boneless, baked chops had the longest cooking times, they were the most ($P < 0.05$) tender. Overall, this study revealed that color, cooking method, and thickness impacted drip loss, cook yield, cook time, cooked color, and tenderness of blade, boneless, and bone-in chops, tenderloins, and roasts.

Introduction: Consumer research has consistently shown that traditionally consumers over-cook pork creating a subpar eating experience (Detienne and Wicker, 1999). With over cooking, pork is drier, tougher and not as flavorful. In the extensive consumer study conducted, consumers evaluated pork cooked to four internal temperatures (62.8, 68.3, 73.9 and 79.4°C) (Moeller et al., 2010b). In that study, consumers responded positively to pork loin chops cooked to 62.8°C. Through a series of research projects, the National Pork Board has shown that there will be essentially no risk from a food safety standpoint in eating pork cooked to 62.8°C and suggested that the minimum cooked internal temperature endpoint of pork be changed to 62.8°C. In 2011, the USDA/FSIS changed the internal doneness temperature from 71.1°C to 62.8°C with a three-minute rest time after cooking to improve the pork eating experience (FSIS, 2013). However, how tenderness and water holding capacity is affected in pork chops differing in thickness and color score cooked to 62.8°C is unknown.

Objectives: The objective was to understand the effect of pork loin color (National Pork Board Color Quality Standards 2 and 4) on water holding capacity, chop thickness, Chop type, and cook method on pork cooked to 62.8°C on cook time, cook yield and Warner-Bratzler shear force (WBSF).

Materials and Methods:

Sample Selection

Boneless and bone-in pork loins (IMPS 413 and 410, respectively) were purchased commercially on three different selection trips from Smithfield Foods in Sioux Falls, SD. The loins were selected to represent the National Pork Board subjective lean color scores of 2 and 4 (National Pork Board, 2011). The Smithfield Foods plant was selected as pigs from varying genetics are harvested and processed. It was determined by Smithfield personnel that selection at this plant would be most representative of pigs harvested in the US pork industry. Color score was determined by trained color evaluators (n = 2) using National Pork Board color cards based on color in the M. *Longissiumus dorsi* at the blade end of the loin. pH was also determined. Vacuum-packaged loins were commercially transported to Texas A&M University in College Station, TX and aged 14 to 19 days. For fabrication, loins were weighed in the original vacuum-package, removed from the package, dried slightly with a paper towel, reweighed, and percentage purge was calculated. Package purge was not obtained for bone-in loins.

For the bone-in loins, the tenderloin (IMPS 415) was removed first, denuded, and randomly assigned to treatments. The sirloin and blade end were removed to leave no more than 8 ribs present. The bone-in ribeye chops (IMPS 1410B) were Chop using a band saw (400, Marel, Norwich, England) to 1.3, 1.9 or 2.5 cm thick. Twelve chops were Chop from each loin, assuring that a portion of the rib bone was present in each chop and randomly assigned to cooking treatment.

The blade end of the boneless loins was removed first and set aside until there were three blade ends available. Once three blade ends were available, blade chops (IMPS 1413.4) were Chop to 1.3, 1.9 or 2.5 cm, and randomly assigned to cooking treatments. Three blade ends within color score were used to obtain 12 chops or 1 chop per treatment. After the blade and sirloin ends were removed, the boneless center-Chop chops (IMPS 1413.1) were Chop to 1.3, 1.9 or 2.5 cm, and randomly assigned to cooking treatments. Twelve boneless chops were Chop from each loin.

From the boneless loins defined above, boneless loin roasts (0.9 and 1.8 kg roasts) were Chop from loins with color score 4. Whole boneless center-Chop loin roasts were Chop into 2.7 kg roasts from loins with color score 2. Each whole boneless center-Chop loin was randomly assigned to treatment.

Water holding capacity, pH, and color

Drip loss (%), a measure of water holding capacity, was determined according to a modified method of Kauffman (1986). From raw chops and roasts, two 10 g sample cubes were removed from the posterior end of each chop or roast. Each 10 g sample was weighed and suspended by a paper clip and placed in a plastic bag (B01062, Nasco, Fort Atkinson, WI) sealed to assure that no evaporative water loss occurred. After storage for 24 hours at 4°C, the samples were reweighed and drip loss (%) was calculated based on beginning sample weight ((raw weight – drip weight) / raw weight * 100). Drip loss was used as an indication of water holding capacity. Percent purge was obtained from the boneless loins by weighing the entire package, weighing the loin, and then weighing the package. Purge was not collected from the bone-in loins because the bone-in loins were not individually packaged.

Initial loins, chops and roasts were evaluated for raw objective color using a Minolta Chromameter (Spectro-photocolorimeter Minolta CR-400; Konica Minolta Sensing, Inc., Osaka, Japan) calibrated daily using a white tile (Y = 94.3, x = 0.3130, y = 0.3199). Cooked color was also evaluated on the chops and roasts. Three L*, a*, and b* color space values were recorded from each loin, chop or roast. The initial loin color values were obtained in the plant on the surface of the boneless loin and the M. *Longissiumus dorsi* at the blade end of the bone-in loin. For the raw samples, the chop or roast was allowed to bloom for twenty minutes and color measurements were taken in triplicates on different sites on the chop Chop surface or the loin surface of the roasts. For the cooked samples, the chop/roasts were Chop in half and color measurements were taken from the inside of the chop/roast to observe the internal color when cooked to 62.8°C.

Duplicate pH measurements for the initial loin, chop, and roast were taken with a pH meter (HI98162, Hanna Instruments, Woonsocket, RI). The pH probe was calibrated daily using pH 4 and 7 standard solutions. The initial loin pH values were taken at the anterior and posterior ends of the boneless loins and between ribs 1 and 2 and 7 and 8 for the bone-in loins. The chop/roast pH values were taken in duplicate form each chop or roast.

Cooking Methods

Four different cooking treatments were used for the bone-in chops, boneless chops, and blade chops within Chop thickness. Each chop was either cooked by an outside gas grill, oven baked, pan sautéed, or pan fried and each roast including the tenderloins were cooked by the outside gas grill and the oven baking methods. The outside gas grill (Performance 4-Burner Liquid Propane Gas Grill with 1-side Burner, Char-Broil LLC. Columbus, GA) was preheated to ensure a grill temperature of 176.7°C. The chops and roasts were cooked with the lid closed and the lid was only open to flip samples or to put new ones on the grill. The grill maintained a temperature of 176.7°C throughout the cooking process.

The chops and roasts were baked in a gas oven (GE Profile Freestanding Self Cleaning Gas Range, General Electric, Rapid City, SD) at 176.7°C on a stainless-steel pan (26639 Petite Roast Pan with Rack, Chicago Metallic, Chicago, IL). Pans were arranged so that air circulation was not blocked in the oven.

Chops were pan sautéed and pan fried in an enamel covered cast iron flat pan (EC11S43 Enameled Cast Iron Skillet, 11-inch, Lodge, South Pittsburg, TN) on a gas stove top (GE Profile Freestanding Self Cleaning Gas Range, General Electric, Rapid City, SD). For stove top cooking applications, a copper plate (10" Large Copper Heat Diffuser/defroster plate, Bella Copper, Ventura, CA) was inserted between the pan and the heat source to assure even distribution of heat across the pan surface. The pan surface temperature was 176.7°C prior to cooking for pan sauté and pan fry. For pan sauté and pan fry, 2 tablespoon of canola oil was added to the pre-heated pan. For the pan sauté, pork chops were dusted with flour, weighed before and after flouring to account for the amount of pickup, and placed in the pre-heated pan and oil. This resulted in 24 treatments for each Chop including the bone-in ribeye, boneless loin chops, and blade chops.

Beginning raw weight, pickup weight (if applicable), cooked weight, cook yield, total cook time, and final internal cook temperature were recorded. Surface temperature of each cooking method was monitored by an infrared reader (IRT-2, Thermoworks, Salt Lake City, UT). Internal temperature was monitored for each chop by inserting an iron-constantan thermocouple (Omega Engineering, Stanford, CT) into the geometric center of the chop or roast. For each cooking method, chops and roasts were cooked to 31.4°C flipped and completed cooking until the final internal temperature of 62.8°C was reached.

Warner-Bratzler Shear Force (WBSF)

After cooking, chops were covered with plastic wrap (Food Service Film Roll, Members Mark, Bentonville, AR) to minimize evaporative losses and cooled overnight at 4°C. Chops were removed from the cooler and brought to room temperature before coring. Four to six, 1.3 cm cores were removed perpendicular to the muscle fiber orientation. Cores were sheared using a United Testing machine (United SSTM-500, Huntington Beach, CA) at a cross-head speed of 200 mm/min using a 500 g load cell, and a 1.02 cm thick V-shape blade with a 60° angle and a half-round peak.

Statistical Analyses

Data was analyzed by Chop type using Analysis of Variance and an alpha $\leq$ 0.05 with SAS (v9.4, SAS Institute, Inc., Cary, NC). Selection trip was included in the model as a random effect and animal within NPB color standard was a fixed effect. The main effects of Chop, color, Chop thickness or roast weight, cooking method and their interactions were identified as main effects. Least squares means were calculated and if differences in effects were reported in the Analysis of Variance, differences in least squares means were determined using the pdiff function.

Results and Discussion:

Raw Analysis

The initial values from the blade-end of whole pork loins for color, pH and purge are reported in Table 1. As expected, 2-color score loins for both the bone-in and boneless loins were lower in subjective color than ($P < 0.0001$) the color scores for 4-color score loins. The NPB color standards (National Pork Board, 2011) suggested that loins with a color score of 2 should have a Minolta L* color space value of approximately 55 and loins with a 4-color score should have Minolta L* color space values of approximately 43. The Minolta L* color space values were slightly elevated from those reported by National Pork Board (2011) but were proportionally different. Minolta instruments may provide slightly different values.

The a* values for the bone-in loins was much higher than ($P < 0.0001$) the boneless loins with the bone-in color 2 loin having the highest a*. The bone-in color 2 loins were also the highest ($P < 0.0001$) for the b* values, followed by the bone-in color 4 loins, the boneless color 2, and finally, the boneless color 4. The pH values were significantly higher ($P < 0.0001$) for each loin type color 4 when compared to the color twos of each loin type. Purge was only collected from the boneless loins where the color 4 loins had significantly less ($P < 0.0001$) purge than the color 2 loins.

These results indicated that loins within color score differed as expected and as previously reported for fresh loins differing in color scores.

Objective color, pH, and drip loss were examined for raw pork blade chops (Table 2), boneless pork loin chops (Table 3), and raw pork bone-in pork loin chops (Table 4) by main effects. The L* and b* color space values differed ($P < 0.0001$) in blade, boneless loin and bone-in loin chops from the 2 and 4 color score loin treatments. Chops from color score 2 loins were lighter and had more yellow color compared to chops from color score 4 loins. Blade chops from color score 4 loins had a higher pH ($P < 0.0001$) and lower ($P = 0.01$) drip loss values than blade chops from color score 2 loins. However, for bone-in and boneless loin chops, pH, while higher in loin chops from color score 4 loins, the pH difference was not as large as reported for blade chops. Additionally, drip loss did not differ in loin chops from color score 2 and 4 loins. pH and drip loss have been related. Huff-Lonergan et al. (2001) showed that pork with a low pH had higher drip loss and lighter color, whereas pork with a higher pH was darker in color and had lower drip loss. The different cooking methods and thickness tended to not affect raw measurement values. As chops were Chop the same raw loin and assigned to treatment, chops would expectantly have similar objective color, pH and drip loss prior to cooking. However, raw bone-in pork loin chops assigned for baking had higher drip loss than chops assigned to pan fry and pan saute cook methods.

Raw measurements for the pork roasts and tenderloins are presented in Table 5. Whole boneless roasts were from color score 2 loins by design. Raw L*, a*, pH, and drip loss were not affected by the cooking treatments. As whole loin roasts were from different loins, this indicated that selection resulted in color score 2 loins that were similar in color scores, pH and drip loss. However, raw b* color space values were higher ($P = 0.02$) for roasts assigned to the baking method than roasts assigned to the grill method. There is no explanation for this difference.

The 0.9 and 1.8 kg roasts were Chop from color score 4 boneless loins. Cooking methods did not affect the raw measurements indicating that loins were similar in raw color, pH and drip loss when assigned to treatment. However, heavier loins were slightly more red ($P = 0.0006$) and yellow ($P = 0.002$), had slightly lower pH ($P = 0.02$) and slightly higher drip loss($P = 0.04$) than lighter weight roasts Tenderloins assigned to bake or grill cooking treatments did not differ in raw color, pH or drip loss.

Cooked Analysis

Cook yield and cook time did not differ for bla chops from color score 2 and 4 loins (Table 6), but cooking method affected cook yield and cook time of blade chops. Cook yield was lowest ($P < 0.0001$) for blade chops cooked on the grill. Baked and pan fried blade chops had similar cook yield and pan sauted blade chops had the highest cook yield. Cook time was highest for baked blade chops. Thicker chops had lower cook yields ($P < 0.0001$) and longer cook times ($P < 0.0001$). As expected, the thinnest blade chop took the least amount of time and had the greatest yield. The cooking method by thickness interaction was present for both cook yield ($P < 0.002$) and cook time ($P < 0.0003$). All of the cooking methods followed the same trend with the thinnest blade chop having the highest yield and shortest cook time and the thickest chop having the least yield and longest cook time. The baking and grilling methods have similar ($P = 0.002$) values for the 1.3 and 1.9 cm thick chops. As the cook time increased for all cooking methods, the yield tended to decrease. Wählby et al. (2000) found that cooking losses for pork chops was strongly dependent on air temperature and not as much on cooking time when pork chops were cooked to the same internal temperature. Chops cooked using the pan sauté method had the highest cook yield and lower cook times. There was also a loin color by thickness interaction ($P = 0.03$) for cook time in blade chops. As the thickness increased for blade chops from loins across color scores, cook time also increased. However, blade chops from color score 2 loins that were 1.3 cm and 1.9 cm thick had lower cook times than blade chops from color score 4 loins. For blade chops that were 2.5 cm thick, blade chops from color score 2 loins had longer cook time than blade chops from color score 4 loins. These are interesting differences, but an explanation of differences is not apparent.

The cooked blade chop measurements for tenderness (Warner-Bratzler shear force (WBSF)) and cooked color are reported in Table 7. Blade chops from loin color score 2 were tougher ($P < 0.0001$) and less red ($P < 0.01$) than blade chops from loin color score 4. For blade chops, cook method did not affect WBSF, but grilled blade chops had lower ($P < 0.005$) L* (were darker) and higher ($P < 0.0001$) b* (more yellow) color space values for internal cook color. Thicker blade chops had similar tenderness ($P = 0.55$), but were redder ($P < 0.0001$) and less yellow ($P < 0.0001$)than thin blade chops cooked to the same internal temperature.

For boneless loin chops, cook yield and cook time were evaluated to determine the differences between loin color scores, cooking methods, and chop thicknesses (Table 8). Boneless loin chops from 4 color score loins had higher ($P < 0.003$) cook yield than boneless loin chops from 2 color score loins; however, cook time did not differ. Boneless grilled loin chops had lower ($P < 0.0001$) cook yield than boneless pan sauted loin chops. As reported for blade chops, baked boneless loin chops had the longest cook time. Boneless pan fried pork chops had the shortest cook times. As boneless pork loin chop thickness increased, cook yield increased ($P < 0.0001$) and cook time increased ($P < 0.0001$). However, there was a cook method by chop thickness interaction for cook time ($P < 0.0004$). In general, as boneless loin chop thickness increased, cook time increased incrementally. Cook times were longest for baked boneless loin chops and cook times were similar for boneless loin chops that were pan fried, grilled and pan sauted across thickness levels. Baking is an indirect heating method. The hot air in the oven transfers to the surface of the meat and then the heat is slowly transferred to the center of the meat through water, fat, and proteins, but mostly water (Baghe-Khandan and Okos, 1981). Kirk (1984) noted that the most important factors when baking in an oven are the rate of evaporation, surface temperature of the food and thickness will impact the times and yields. This may explain by cook times were higher for boneless loin chops that were baked.

The cooked tenderness and color measurements for boneless loin chops are shown in Table 9. Loin color affected tenderness and L*, a*, and b* color space values of cooked boneless loin chops. Chops from color score 4 loins were more tender ($P = 0.01$) , ligher ($P < 0.01$), more red ($P < 0.0001$), and more yellow ($P < 0.009$) than boneless loin chops from color score 2 loins. Cooking method affected in tenderness, L* and a* color space values in boneless loin chops. Boneless loin chops that were pan fry and grilled were tougher ($P = 0.01$) than baked boneless loin chops. Pan sauted boneless loin chops were similar in tenderness to other boneless loin chops. Outside grilling is a unique type of cooking that combines convection and conduction heating to cook (Yancey et al., 2011). Heat is applied indirectly through hot air and directly through contact with the hot grills. The higher temperatures cause myofibrillar protein denaturation and structural changes to the muscle by pushing water from the meat causing a lower yield and tenderness (Davey and Gilbert, 1974). Baked boneless loin chops were lighter ($P < 0.0001$), with more red color ($P < 0.0001$) than grilled boneless loin chops for interior cooked chop color. The thinnest (1.3 cm) boneless loin chops were tougher ($P < 0.02$), with less red color ($P < 0.0001$), and more yellow ($P < 0.0001$) color internally than boneless pork loin chops that were 1.9 or 2.5 cm thick. Similarly, Simmins et al. (1985) reported 1.3 cm grilled pork chops had higher WBSF values and that grilled pork chops that were 1.9 and 2.5 cm did not differ in WBSF values.

Cook yield and cook time for the cooked bone-in chops are reported in Table 10. Cook yield and cook time were not affected by raw loin color score but bone-in loin chops differed in cook yield and cook time by cooking method and chop thickness. Cook yield was highest for pan sauted bone-in loin chops and lowest for grilled bone-in loin chops. Baked and pan fried bone-in loin chops had intermediate cook yields. Pan sauté had the highest cook yield for the three chop types. This could be because the flour coated and protected the muscle fibers from losing water. Cook time was shortest for pan fried bone-in loin chops with pan sauted bone-in loin chops having slightly higher cook time. Grilled bone-in loin chops were intermediate in cook time and baked bone-in loin chops had the longest cook time. Thicker bone-in loin chops had lower cook yields and the longest cook times. For the interaction of cook method by bone-in loin chop thickness, thicker chops had longer cook times across cook methods and as chop thickness increased, cook time increased. However, baked bone-in loin chops had longer cook times and pan fried and pan sauted bone-in loin chops had the shorter cook times across thickness levels.

Least squares means for tenderness and cooked objective color score values of bone-in loin chops are reported in Table 11. Loin color score impacted tenderness, a* and b* values but did not affect L* values. Bone-in loin chops from color score 4 loins were tougher ($P < 0.0001$), had higher ($P = 0.01$) a* color space values and lower ($P = 0.03$) b* color space values when compared to bone-in loin chops from color score 4 loins. Cooking method affected tenderness and objective color values. Pan fried bone-in loin chops were toughest ($P < 0.0001$). Berry and Leddy (1984) suggested that frying caused a thick crust formation that could result in lower tenderness scores. Grilled bone-in loin chops had the lowest L* ($P = 0.04$) and a* ($P = 0.0002$) color space values. Baked bone-in loin chops had the lowest ($P < 0.0001$) b* color space values and grilled bone-in loin chops had the highest b* color space values. Thickness impacted a* and b* color space values. As bone-in loin chop thickness increased, a* color space values also increased ($P < 0.0001$). The thinnest bone-in pork chop had the highest ($P = 0.0002$) b* color space values.

Cook yield, cook time, WBSF values, and objective color values are reported in Table 12 for loin and tenderloin roasts. Baked whole boneless roasts from color score 2 loins had higher cook yield ($P < 0.0001$), longer cook times ($P < 0.0001$) and did not differ ($P > 0.05$) in color or tenderness from grilled whole boneless roasts. For smaller boneless loin roasts that were cut from raw loin color score 4 loins, baked roasts had higher cook yields ($P < 0.0001$), longer cook times, were tougher ($P = 0.009$), and had more red internal cook color ($P < 0.0001$) than boneless loin roasts that were grilled. Heavier boneless loin roasts had lower cook yield ($P = 0.001$), longer cook times ($P = 0.001$), were tougher ($P = 0.001$) and were similar in internal color ($P > 0.05$) to lighter weight boneless loin roasts. Baked tenderloin roasts had higher cook yield ($P < 0.0001$) , longer cook times ($P < 0.0001$) and were more red in internal color ($P = 0.0004$) than grilled tenderloin roasts.

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Table **1**. Least squares means for initial Minolta CIE L*, a*, and b*, and pH on the loin blade end at the time of selection for bone-in and boneless pork loins, and purge (%) at fabrication for boneless pork loins.

Loin type	Color Score	CIE Color Space Values L*	a*	b*	pH	Purge (%)
P-value[e]		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Bone-in	2	52.8[c]	9.3[c]	6.1[d]	5.7[b]	-
Bone-in	4	45.9[a]	8.6[b]	3.8[c]	5.9[c]	-
Boneless	2	56.6[d]	3.7[a]	2.8[b]	5.5[a]	2.1[b]
Boneless	4	50.4[b]	3.8[a]	1.7[a]	5.7[b]	1.1[a]
RMSE[f]		2.01	1.18	0.89	0.14	0.76

[abcd] Mean values within a row followed by the same letter are not significantly different (*P* > 0.05).

[e] P-value from Analysis of Variance table.

[f] RMSE = Root Mean Square Error.

Table 2. Least squares means for raw Minolta CIE L*, a*, and b* color space values, pH, and drip loss values for raw pork blade chop by main effect treatments.

	CIE Color Space Values				Drip
Treatments	L*	a*	b*	pH	Loss (%)
Loin Color Score[c]	<0.0001	0.30	<0.0001	<0.0001	0.01
2	61.7[b]	4.9	5.7[b]	5.3[a]	1.4[b]
4	53.0[a]	5.5	3.9[a]	5.9[b]	0.9[a]
Cook Method[c]	0.56	0.43	0.61	0.71	0.69
Bake	57.0	5.3	4.9	5.7	1.1
Pan Fry	57.4	5.1	4.7	5.7	1.2
Grill	57.3	5.3	4.9	5.7	1.1
Pan Sauté	57.7	5.0	4.8	5.7	1.2
Chop Thickness[c]	0.18	0.36	0.78	0.29	0.62
1.3	57.1	5.3	4.8	5.7	1.1
1.9	57.7	5.1	4.9	5.7	1.2
2.5	57.2	5.1	4.8	5.7	1.1
RMSE[d]	3.50	1.73	1.31	0.16	0.66

[ab] Mean values within a row followed by the same letter are not significantly different ($P > 0.05$).

[c] P-value from Analysis of Variance table.

[d] RMSE = Root Mean Square Error.

Table 3. Least squares means for raw Minolta CIE L*, a*, and b*, pH, and drip loss values for raw boneless pork loin chops by main effect treatments.

	CIE Color Space Values				Drip
Treatments	L*	a*	b*	pH	Loss (%)
Loin Color Score[c]	<0.0001	0.06	<0.0001	<0.0001	0.20
2	60.1[b]	4.4	5.0[b]	5.5[a]	1.6
4	52.7[a]	5.2	4.0[a]	5.8[b]	1.2
Cook Method[c]	0.99	0.17	0.52	0.86	0.22
Bake	56.4	4.7	4.4	5.7	1.5
Pan Fry	56.4	4.8	4.5	5.7	1.3
Grill	56.4	4.9	4.6	5.7	1.4
Pan Sauté	56.4	4.8	4.5	5.7	1.4
Chop Thickness[c]	0.93	0.46	0.80	0.70	0.30
1.3	56.5	4.9	4.5	5.7	1.3
1.9	56.4	4.8	4.5	5.7	1.4
2.5	56.4	4.8	4.5	5.7	1.5
RMSE[d]	2.44	0.90	1.06	0.14	0.86

[ab] Mean values within a row followed by the same letter are not significantly different ($P > 0.05$).
[c] P-value from Analysis of Variance table.
[d] RMSE = Root Mean Square Error.

Table 4. Least squares means for raw Minolta CIE L*, a*, and b*, pH, and drip loss values for raw bone-in loin chop by main effect treatments.

	CIE Color Space Values				Drip
Treatments	L*	a*	b*	pH	Loss (%)
Color Method[c]	<0.0001	<0.0001	<0.0001	0.001	0.99
2	57.5[b]	5.57[b]	4.8[b]	5.6[a]	1.4
4	56.4[a]	3.87[a]	3.5[a]	5.7[b]	0.8
Cook[c]	0.68	0.96	0.78	0.99	0.04
Bake	57.1	4.7	4.1	5.7	1.3[b]
Pan Fry	56.7	4.7	4.1	5.7	1.0[a]
Grill	56.9	4.8	4.2	5.7	1.1[ab]
Pan Sauté	57.1	4.7	3.1	5.7	0.9[a]
Chop Thickness[c]	0.93	0.002	0.30	0.09	0.78
1.3	57.0	5.0[b]	4.2	5.7	1.0
1.9	57.0	4.6[a]	4.2	5.7	1.1
2.5	57.0	4.6[a]	4.0	5.7	1.1
RMSE[d]	2.45	1.07	1.05	0.14	0.89

[ab] Mean values within a row followed by the same letter are not significantly different ($P > 0.05$).
[c] P-value from Analysis of Variance table.
[d] RMSE = Root Mean Square Error.

Table 5. Least squares means for raw Minolta CIE L*, a*, and b*, pH, and drip loss values for raw boneless pork roasts and tenderloin roasts.

Treatments	CIE Color Space Values L*	a*	b*	pH	Drip Loss (%)
Whole Boneless Roasts Color Score 2					
Cook Method[c]	0.19	0.49	0.02	0.83	0.48
Bake	58.7	5.8	6.4[b]	5.6	5.6
Grill	57.4	5.5	5.6[a]	5.6	5.6
RMSE[d]	2.98	1.21	1.18	0.12	1.04
Chop Boneless Roasts Loin Color Score 4					
Cook Method[c]	0.37	0.05	0.59	0.31	0.75
Bake	46.4	5.0	2.2	6.0	0.87
Grill	45.8	5.4	2.3	6.0	0.82
Raw Chop Weight[e]	0.46	0.0006	0.002	0.02	0.04
0.9 kg	45.8	4.8[a]	1.9[a]	6.1[b]	0.51[a]
1.8 kg	45.4	5.6[b]	2.6[b]	6.0[a]	1.18[b]
RMSE[d]	3.42	1.00	1.03	0.18	0.76
Tenderloin					
Cook Method[c]	0.99	0.91	0.11	0.94	0.99
Bake	48.4	7.8	3.3	5.9	0.75
Grill	48.4	7.9	3.9	5.9	0.75
RMSE[d]	2.72	1.51	1.18	0.20	0.34

[ab] Mean values within a row followed by the same letter are not significantly different ($P > 0.05$).
[c] P-value from Analysis of Variance table.
[d] RMSE = Root Mean Square Error.

Table 6. Least squares means for cook yield and cook time for the cooked blade chop main effects and significant ($P < 0.05$) interactions.

Treatments	Cook Yield (%)	Cook Time (min.)
Loin Color Score[e]	0.95	0.49
2	89.8	12.8
4	90.2	13.8
Cook Method[e]	<0.0001	<0.0001
Bake	89.9[b]	24.1[b]
Pan Fry	90.5[b]	9.2[a]
Grill	85.4[a]	10.0[a]
Pan Sauté	94.3[c]	9.9[a]
Chop Thickness[e]	<0.0001	<0.0001
1.3 cm	91.9[c]	7.8[a]
1.9 cm	90.2[b]	13.2[b]
2.5 cm	87.9[a]	18.9[c]
Cook Method by Chop Thickness[e]	0.002	0.0003
Bake by 1.3 cm	90.4[de]	16.3[d]
Bake by 1.9 cm	90.2[de]	24.4[e]
Bake by 2.5 cm	89.0[cd]	31.6[f]
Pan Fry by 1.3 cm	93.0[f]	4.5[a]
Pan Fry by 1.9 cm	90.4[de]	9.0[b]
Pan Fry by 2.5 cm	88.0[bc]	14.2[cd]
Grill by 1.3 cm	86.6[b]	5.6[a]
Grill by 1.9 cm	85.6[b]	10.0[b]
Grill by 2.5 cm	83.8[a]	14.4[cd]
Pan Saute by 1.3 cm	97.4[g]	4.7[a]
Pan Saute by 1.9 cm	94.5[f]	9.5[b]
Pan Saute by 2.5 cm	90.9[e]	15.5[cd]
Loin Color Score by Chop Thickness[e]		0.03
2 by 1.3 cm		6.9[a]
2 by 1.9 cm		12.3[b]
2 by 2.5 cm		19.2[e]
4 by 1.3 cm		8.6[a]
4 by 1.9 cm		14.1[c]
4 by 2.5 cm		18.7[d]
RMSE[f]	3.87	4.49

[abcd] Mean values within a row followed by the same letter are not significantly different ($P > 0.05$).
[e] P-value from Analysis of Variance table.
[f] RMSE = Root Mean Square Error.

Table 7. Least squares means for Warner-Bratzler Shear Force, cooked Minolta CIE L*, a*, and b* color space values for the cooked blade chops.

Treatments	Warner-Bratzler Shear Force Values (kg)	CIE Color Space Values L*	a*	b*
Loin Color Score[d]	<0.0001	0.38	0.01	0.51
2	1.9[b]	78.1	4.2[a]	11.2
4	1.6[a]	76.9	6.0[b]	11.1
Cook Method[d]	0.06	0.005	0.69	<0.0001
Bake	1.6	77.5[b]	5.2	10.7[a]
Pan Fry	1.8	77.6[b]	5.1	11.1[b]
Grill	1.8	76.4[a]	4.9	11.7[c]
Pan Sauté	1.7	78.3[b]	5.2	11.0[ab]
Chop Thickness[d]	0.55	0.42	<0.0001	<0.0001
1.3 cm	1.8	77.4	4.4[a]	11.6[b]
1.9 cm	1.7	77.8	5.2[b]	10.9[a]
2.5 cm	1.7	77.2	5.8[c]	10.9[a]
RMSE[e]	3.87	4.49	2.18	1.50

[abc] Mean values within a row followed by the same letter are not significantly different (*P* > 0.05).
[d] P-value from Analysis of Variance table.
[e] RMSE = Root Mean Square Error.

Table 8. Least squares means for cook yield and cook time for cooked boneless loin chops.

Treatments	Cook Yield (%)	Cook Time (min.)
Loin Color Score[e]	0.003	0.05
2	87.3[a]	16.4
4	90.4[b]	15.0
Cook Method[e]	<0.0001	<0.0001
Bake	88.6[b]	26.6[d]
Pan Fry	89.4[b]	10.8[a]
Grill	84.6[a]	12.9[b]
Pan Sauté	92.9[c]	12.5[c]
Chop Thickness[e]	<0.0001	<0.0001
1.3 cm	90.9[c]	8.8[a]
1.9 cm	88.5[b]	16.4[b]
2.5 cm	87.2[a]	21.9[c]
Cook Method by Chop Thickness		0.0004
Bake by 1.3 cm		17.9[e]
Bake by 1.9 cm		26.7[f]
Bake by 2.5 cm		35.2[g]
Pan Fry by 1.3 cm		5.2[a]
Pan Fry by 1.9 cm		11.5[b]
Pan Fry by 2.5 cm		15.8[d]
Grill by 1.3 cm		6.4[a]
Grill by 1.9 cm		14.2[cd]
Grill by 2.5 cm		18.2[e]
Pan Saute by 1.3 cm		5.7[a]
Pan Saute by 1.9 cm		13.2[bc]
Pan Saute by 2.5 cm		18.4[e]
RMSE[f]	4.27	4.58

[abcd] Mean values within a row followed by the same letter are not significantly different ($P > 0.05$).
[e] P-value from Analysis of Variance table.
[f] RMSE = Root Mean Square Error.

Table 9. Least squares means for Warner-Bratzler Shear Force, cooked Minolta CIE L*, a*, and b* color space values for the cooked boneless loin chops.

Treatments	Warner-Bratzler Shear Force Values (kg)	CIE Color Space Values L*	a*	b*
Loin Color Score[e]	0.01	0.01	<0.0001	0.009
2	2.4^{b}	78.7^{b}	4.1^{a}	10.7^{a}
4	2.2^{a}	76.7^{a}	5.8^{b}	11.1^{b}
Cook Method[e]	0.01	<0.0001	<0.0001	0.11
Bake	2.2^{a}	78.6^{c}	5.0^{b}	10.6
Pan Fry	2.4^{b}	77.4^{ab}	5.2^{b}	10.9
Grill	2.3^{b}	77.0^{a}	4.4^{a}	11.1
Pan Sauté	2.3^{ab}	77.8^{b}	5.2^{b}	10.9
Chop Thickness[e]	0.02	0.89	<0.00010.0001	
1.3 cm	2.4^{b}	77.6	4.3^{a}	11.3^{b}
1.9 cm	2.2^{a}	77.8	5.1^{b}	10.8^{a}
2.5 cm	2.2^{a}	77.7	5.3^{b}	10.6^{a}
RMSE[f]	0.48	2.71	1.31	1.54

[abcd] Mean values within a row followed by the same letter are not significantly different ($P > 0.05$).

[e] P-value from Analysis of Variance table.

[f] RMSE = Root Mean Square Error.

Table 10. Least squares means for cook yield and cook time for the cooked bone-in loin chops.

Treatments	Cook Yield (%)	Cook Time (min)
Loin Color Score[e]	0.89	0.53
2	92.0	12.3
4	92.4	12.1
Cook Method[e]	<0.0001	<0.0001
Bake	91.3[b]	22.6[d]
Pan Fry	92.8[c]	7.5[a]
Grill	87.9[a]	10.3[c]
Pan Sauté	96.8[d]	8.6[b]
Chop Thickness[e]	<0.0001	<0.0001
1.3 cm	93.2[b]	8.0[a]
1.9 cm	92.6[b]	11.6[b]
2.5 cm	90.8[a]	17.1[c]
Cook Method by Chop Thickness		<0.0001
Bake by 1.3 cm		16.1[e]
Bake by 1.9 cm		21.4[f]
Bake by 2.5 cm		30.2[g]
Pan Fry by 1.3 cm		4.3[a]
Pan Fry by 1.9 cm		7.0[b]
Pan Fry by 2.5 cm		11.2[c]
Grill by 1.3 cm		6.7[b]
Grill by 1.9 cm		10.5[c]
Grill by 2.5 cm		13.7[d]
Pan Saute by 1.3 cm		4.8[a]
Pan Saute by 1.9 cm		7.8[b]
Pan Saute by 2.5 cm		13.2[d]
RMSE[f]	3.57	4.15

[abcd] Mean values within a row followed by the same letter are not significantly different ($P > 0.05$).
[e] P-value from Analysis of Variance table.
[f] RMSE = Root Mean Square Error.

Table 11. Least squares means for Warner-Bratzler Shear Force, cooked Minolta CIE L*, a*, and b* color space values for the cooked bone-in loin chops.

Treatments	Warner-Bratzler shear force values (kg)	CIE Color Space Values L*	a*	b*
Loin Color Score[e]	<0.0001	0.89	0.01	0.03
2	2.2[a]	77.0	4.9[b]	11.1[a]
4	2.3[b]	77.1	4.2[a]	11.6[b]
Cook Method[e]	<0.0001	0.04	0.0002	<0.0001
Bake	2.1[a]	77.2[b]	4.6[b]	10.6[a]
Pan Fry	2.4[c]	77.3[b]	4.8[b]	11.6[bc]
Grill	2.3[b]	76.4[a]	4.1[a]	11.8[c]
Pan Sauté	2.2[ab]	77.4[b]	4.6[b]	11.3[b]
Chop Thickness[e]	0.06	0.12	<0.0001	0.0002
1.3 cm	2.3	76.7	4.0[a]	11.7[b]
1.9 cm	2.3	77.2	4.6[b]	11.3[a]
2.5 cm	2.2	77.3	5.1[c]	11.0[a]
RMSE[f]	0.38	3.25	1.36	1.40

[abcd] Mean values within a row followed by the same letter are not significantly different ($P > 0.05$).
[e] P-value from Analysis of Variance table.
[f] RMSE = Root Mean Square Error.

Table 12. Least squares means for cook yield, cook time, Warner-Bratzler Shear Force, cooked Minolta CIE L*, a*, and b* color space values for cooked loin and tenderloin roasts.

	Cook	Cook	Warner-Bratzler	CIE Color Space Values		
Treatments	Yield (%)	Time (min)	Shear Force Values (kg)	L*	a*	b*
Whole Boneless Roasts, Raw Loin Color 2						
Cook Method[c]	<0.0001	<0.0001	0.62	0.85	0.28	0.34
Bake	84.7[b]	97.9[b]	2.5	77.3	4.4	9.9
Grill	74.7[a]	66.3[a]	2.4	77.4	4.0	10.4
RMSE[d]	3.99	11.62	0.35	3.40	1.19	1.84
Boneless Roasts, Raw Loin Color 4						
Cook Method[c]	<0.0001	<0.0001	0.009	0.41	<0.0001	0.23
Bake	85.1[b]	76.0[b]	2.3[a]	74.3	6.6[b]	8.9
Grill	72.6[a]	50.6[a]	2.6[b]	74.9	4.4[a]	9.4
Raw Weight[c]	0.001	0.001	0.001	0.21	0.81	0.17
0.9 kg	80.5[b]	58.8[a]	2.3[a]	75.1	5.6	8.8
1.8 kg	77.1[a]	67.8[b]	2.6[b]	74.2	5.4	9.4
RMSE[d]	5.02	13.3	0.49	3.01	1.89	1.70
Tenderloin						
Cook Method[c]	<0.0001	<0.0001	0.14	0.76	0.0004	0.31
Bake	89.6[b]	41.2[b]	1.9	68.7	11.5[b]	11.1
Grill	81.3[a]	28.5[a]	2.1	69.0	9.3[a]	11.6
RMSE[d]	2.79	6.86	0.40	3.05	1.76	1.63

[ab] Mean values within a row followed by the same letter are not significantly different ($P > 0.05$).
[c] P-value from Analysis of Variance table.
[d] RMSE = Root Mean Square Error.