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Pork Quality Attributes and Eating Characteristics Among Different Premium and Commodity Pork Loin Programs[a]

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Abstract: Pork branding is a common tool used to differentiate products based on quality to assist consumers in making purchasing decisions. Most pork processers have premium pork programs with different parameters related to color, marbling, and other quality factors, though many differences in specific criteria exist among programs. The objective of this study was to assess differences in pork quality and the associated eating experience of different premium and commodity pork loin programs available in the retail market. Loins ($n = 30$/brand) from 7 branded (PRE A, B, C, D, and E) and commodity (COM A and B) programs were acquired and fabricated at 14–15 d post-box date into 2.54-cm chops for visual color, marbling, pH, intramuscular fat, drip loss, purge loss, shear force, and trained sensory panels. Overall, few differences were found among products for most of the quality traits evaluated. One commodity brand, COM B, had higher ($P < 0.05$) loin L^* values and chop L^* values and had lower chop a^* values, visual color scores, pH, and drip loss than other treatments, but it did not differ ($P > 0.05$) in initial juiciness, sustained juiciness, or any tenderness measurement. The only quality measurement that was associated with changes in eating experience was shear force value, with the PRE C product having the highest ($P < 0.05$) Warner-Brazler shear force and slice shear force values and the associated lowest ($P < 0.05$) myofibrillar tenderness and overall tenderness ratings in the sensory panels. There were no differences ($P > 0.05$) among any treatment for initial juiciness, sustained juiciness, and pork flavor intensity. The results from this study indicate that the range of pork quality differences sold domestically among the evaluated premium and commodity programs is minimal and does not result in associated differences in eating experience.

Key words: color, marbling, branding, sensory, palatability, pork
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Introduction

Unlike beef, there is no United States Department of Agriculture (USDA) quality grading system for pork that focuses on segregating products based on eating quality. Therefore, branded programs have been pivotal to categorize pork products into different quality categories (USDA, 1985; Grunert et al., 2004). Without guidelines from the USDA, there is no single definition or set quality parameters used universally within the pork industry, allowing for inconsistencies among brand quality parameters (Huff-Lonergan et al., 2002; Buhr et al., 2004; Towers, 2016). Pork branding and differentiation has increased in popularity in recent years, in part to increase consumer transparency and to improve the expected eating experience (Buhr et al., 2004). Most pork sensory research has been centered around inherent differences within quality parameters such as marbling, diet, breed, etc. (Bohrer and Boler, 2017). However, there is minimal research that has evaluated variability and quality characteristics among different branded programs. Pork is the number one consumed protein in the world (USDA, 2023), so understanding the eating quality differences between established quality-based programs is critical for the pork industry.

Pork quality has historically had two main focuses: color and marbling, with pH and water holding capacity (WHC) being highly related to color (Lammers et al., 2007; Boler et al., 2010; Bohrer and Boler, 2017). Color, being an indicator of pH and therefore WHC, has been the long-standing standard for the pork industry, especially for exports to Japan (Towers, 2016). Pork quality, but mostly color, is the main driver for the global export market with China and Japan as some of the top destinations for US pork based on value (Office of the United States Trade Representative, 2019; Pork Checkoff, 2021). With exports accounting for $8.1B in 2021, the highest in history, pork quality is more important now than ever before (Pork Checkoff, 2021). Japan has the strictest pork import market in the world, having requirements for color, firmness, and fat quality requiring a Japanese Color Score range of over 3 out of 6 and a marbling score of over 3 out of 10 (Cravens, 1999). To meet the demand of the Japanese market and other export markets, most US pork processors have placed color at the forefront of importance, regardless of its impact on eating quality (Cravens, 1999).

US consumers have also become more aware of pork color and quality over the past few decades. The connection between color and pork quality increased in importance after the famous "*Pork, the other white meat*" campaign launched in 1987 and the associated incidence of pale, soft, and exudative (PSE) pork increased in the 1990s (Norman et al., 2003; Martinez and Zering, 2004; NPB and Pork Checkoff, 2021). The slogan was used to reinforce pork as a healthy red meat option offering the least amount of fat per 3-ounce serving, and therefore increased sales and popularity (NPB and Pork Checkoff, 2021; OECD, 2023). While the slogan was successful, it also increased the purchasing of paler colored pork, damaging the consumers' association with pork color (Norman et al., 2003). The combined push for leaner pork, and higher carcass weights led to a decrease in pork quality and increase in PSE incidence, thus increasing the importance of high-quality pork without sacrificing the health and growth improvements (Martinez and Zering, 2004). The industry now aims to produce pork carcasses with a focus on meat quality improvement and consistency while still increasing the average daily gain to feed the growing population (Tokach et al., 2016; Willson et al., 2020). Combining the need for higher quality pork to be competitive in the Japanese markets and the need to differentiate higher quality pork to US consumers, high quality pork branded programs have increased in numbers. Therefore, the objective of this study was to assess the differences in pork quality attributes and eating experience among different premium and commodity pork programs available in the US retail market.

Materials and Methods

Sample collection and fabrication

Pork loins ($n = 30$/brand; IMPS #414) from 5 premium brands (PRE A, B, C, D, and E) and 2 commodity brands (COM A and B) available in the retail market were procured from purveyors and meat processors and shipped to Kansas State University. Loins represented popular quality-focused brands from numerous packers and processors, with all loins from the same treatment coming from the same processing facility. Upon arrival, the loins were aged to 14 or 15 d post-box date at 2°C to 4°C without exposure to light. Before fabrication, the loins were weighed in the package, removed, dried off with paper towels, and reweighed for determination of loin weight. The bags were washed and dried overnight before being weighed for calculation of purge loss percentage.

Color, pH, marbling, and drip loss

Objective color and subjective color and marbling scores were taken on the whole loin immediately after removing the loin from the package on the ventral surface of the loin. Objective color was taken using a HunterLab Miniscan Spectrophotometer (Illuminant A, 1 inch aperture, 10° observer; Hunter Associates Laboratory, Reston, VA) following the American Meat Science Association (AMSA) Color Guidelines (King et al., 2023). The subjective color scores and marbling scores were determined by Kansas State University personnel using the National Pork Board standards (NPB, n.d.).

The loins were sliced into eight 2.54-cm chops immediately posterior to the M. spinalis dorsi using a commercial slicer (Trief Model PUMA 700F, Trief USA Inc., Shelton, CT). Each chop was assigned one of the following designations from anterior to posterior: 1. lab assay (immediate color, bloom color, marbling, pH, and fat), 2. Warner-Bratzler shear force (WBSF), 3. slice shear force (SSF), 4 and 5. sensory panels, 6. drip loss. The chops designated for lab assays had L^*, a^*, and b^* color readings taken immediately after slicing and after a 30-min bloom time. On the same chop, pH was taken with a pH meter (model HI 99163; Hanna Instruments, Smithfield, RI) inserted into the geometric center of the chop. Initial and bloomed subjective color and marbling scores were determined using NPB standards (NPB, n.d.). All chops were vacuum-sealed and frozen at −20°C until subsequent analysis.

Drip loss cores were taken at the time of fabrication on the chop designated for drip loss. Drip loss was measured by taking two 2.54-cm cores from the center portion of the chop, weighing each and placing them on top of wire netting in plastic containers held at 2°C–4°C to allow the purge to accumulate underneath. The cores were reweighed at 48 h and presented as a percentage of the weight lost, averaged between the two cores.

Intramuscular fat and shear force

The chloroform:methanol extraction method described by Folch et al. (1957) was used for determination of intramuscular fat (IMF) content. For WBSF, the protocols outlined by the AMSA (AMSA, 2015) were followed using an Instron testing machine (Model 5569, Instron Corp., Canton, MA). For SSF, procedures described by Shackelford et al. (1999) were followed. Prior to shear force determination, samples were thawed (2°C–4°C) overnight and cooked to a peak internal temperature of 71°C on a 177°C clamshell style grill (Cuisinart Griddler Deluxe, East Windsor, NJ), with temperatures monitored using calibrated Thermopens (ThermoWorks Thermopens Mk4) inserted into the thickest portion of the chop.

Trained sensory panels

The AMSA sensory guidelines (AMSA, 2015) were followed for the training of sensory panelists. The trained sensory panel training protocol, sample evaluation protocol, scaling, and anchors used were identical to those described by Rice et al. (2019). Trained sensory panelists evaluated one sample from each of the programs in a random order within a panel session, for a total of 20 trained panel sessions. Cooking procedures for trained sensory panels followed the procedures previously outlined for WBSF and SSF. Cooked samples were sliced into 2.5-cm thick × 1-cm × 1-cm cuboids using a slicing guide. Panelists were provided 2 cuboids per sample for evaluation. Each panelist was given a common sample for the warm-up, which was discussed among the panelists prior to treatment sample evaluation. The warm-up sample was used as a method for panel calibration and to prevent panelist drift throughout the panel sessions. Panelists were served all samples in individual sensory booths under red incandescent lights at low intensity (<107.64 lumens). During each session, panelists were given an electronic tablet (Lenovo TB-8505F, Morrisville, NC) using Qualtrics (Version 2417833; Qualtrics Software, Provo, UT) for the sample ballot. Deionized water, unsalted crackers, and apple slices were provided as palate cleansers.

Statistical analysis

SAS (Version 9.4; SAS Institute Inc., Cary, NC) PROC GLIMMIX was used for all statistical analyses, using a completely randomized design with the fixed effect of loin brand and the random effects of panel time and peak internal temperature for sensory panel data. For all analyses, loin served as the experimental unit, the Kenward-Roger adjustment was used, and α was set at 0.05.

Results

In Table 1, objective color, subjective color, and marbling scores assessed on the intact loins and chops are presented. There were differences ($P < 0.05$) for every factor, with COM B differing from the other treatments for most attributes. For L^* values, COM B had the highest value ($P < 0.05$) or the palest color compared to all other treatments, while the remaining treatments did not differ ($P > 0.05$). The a^* values followed a similar trend, as COM B had a lower ($P < 0.05$) a^* value than PRE C, PRE E, and COM A but was similar ($P > 0.05$) to PRE A, PRE B, and PRE D. However, b^* had fewer differences. The COM B, PRE A, and PRE C treatments had lower ($P < 0.05$) b^* values than PRE B, PRE D, and PRE E, while COM A was similar ($P > 0.05$) to all treatments other than PRE E. Overall, objective color scores followed a similar trend to a^* values. The COM B loins had a lower ($P < 0.05$) color score (lighter color) than PRE A, PRE C, and PRE E but were similar ($P > 0.05$) to PRE B, PRE D, and COM A. Few differences were found among treatments for marbling, with only PRE A and PRE E having more ($P < 0.05$) marbling than COM A.

Immediately after slicing the same quality measures were taken on the chop and results are displayed in Table 1. Almost identical to the loin data, COM B was the lowest ($P < 0.05$) in both L^* and a * values, providing evidence that the loin measurements were representative of the associated chop measures. The

Table 1. Loin immediate color and marbling attributes ($n = 30$/brand) of premium and commodity pork loin brands

Location	Treatment	L^{*1}	a^{*2}	b^{*3}	Marbling[4]	Color[5]
Loin	Premium A	57.2[b]	14.3[abc]	11.8[c]	2.8[a]	3.6[ab]
	Premium B	57.4[b]	14.1[bc]	12.6[ab]	2.1[b]	3.3[bc]
	Premium C	57.7[b]	14.3[ab]	11.9[c]	2.2[b]	3.6[a]
	Premium D	57.9[b]	14.2[abc]	12.6[ab]	2.4[b]	3.4[abc]
	Premium E	57.1[b]	14.8[a]	13.1[a]	3.1[a]	3.5[ab]
	Commodity A	57.0[b]	14.6[ab]	12.3[bc]	2.0[b]	3.3[bc]
	Commodity B	62.3[a]	13.7[c]	11.9[c]	2.0[b]	3.1[c]
	SE[6]	0.55	0.23	0.20	0.13	0.11
	P value	<0.01	0.03	<0.01	<0.01	0.03
Chop	Premium A	59.8[b]	13.7[a]	11.4[ab]	-	3.1[abc]
Pre-bloom	Premium B	59.7[bc]	12.5[c]	10.9[c]	-	3.4[a]
	Premium C	59.4[bc]	12.5[c]	10.1[d]	-	3.2[ab]
	Premium D	59.4[bc]	13.3[ab]	11.6[a]	-	3.1[abc]
	Premium E	58.3[c]	13.1[abc]	11.5[ab]	-	3.5[ab]
	Commodity A	59.1[bc]	12.9[bc]	11.1[bc]	-	3.0[bc]
	Commodity B	64.6[a]	11.8[d]	10.3[d]	-	2.8[c]
	SE[6]	0.80	0.24	0.16	-	0.18
	P value	<0.01	<0.01	<0.01	-	0.02
Chop	Premium A	59.7[bc]	15.6[a]	14.2[ab]	2.7[a]	3.3[bc]
Post-bloom	Premium B	59.7[bc]	14.8[a]	14.0[b]	2.2[cd]	3.4[bc]
	Premium C	59.7[bc]	15.2[a]	13.6[bc]	2.2[cd]	3.3[bc]
	Premium D	59.9[b]	15.4[a]	14.7[a]	2.6[bc]	3.6[ab]
	Premium E	58.3[c]	14.8[a]	14.1[ab]	3.2[a]	3.7[a]
	Commodity A	59.4[bc]	15.2[a]	14.3[ab]	1.8[d]	3.1[cd]
	Commodity B	61.7[a]	14.0[b]	13.2[c]	2.1[d]	2.9[d]
	SE[6]	0.55	0.23	0.20	0.15	0.13
	P value	<0.01	0.03	<0.01	<0.01	<0.01

[a–d]Means within the same section of the column without a common superscript differ ($P < 0.05$).

[1]L^*: 0 = black, 100 = white.

[2]a^*: −60 = green, 60 = red.

[3]b^*: −60 = blue, 60 = yellow.

[4]Marbling scores determined by National Pork Board Standards (NPB, n.d.).

[5]Color scores determined by National Pork Board Standards (NPB, n.d.).

[6]SE (largest) of the least-squares means.

PRE E treatment was darker, with lower ($P < 0.05$) L^* values when compared to PRE A and COM B, with all other treatments similar ($P > 0.05$). The PRE A chops had a higher ($P < 0.05$) a^* value than PRE B, PRE C, COM A, and COM B, but were similar ($P > 0.05$) to PRE D and PRE E. For subjective measures, the COM B treatment was lower ($P < 0.05$) than PRE B, PRE C, and PRE E, but was similar ($P > 0.05$) to all other treatments. These results closely resemble the loin data with limited differences in color and marbling identified among the treatments for chops.

After a 30-min blooming period, objective color, subjective color, and marbling of the same chops were remeasured and are outlined in Table 1. Bloomed color followed a similar trend to initial chop color and loin color data. The COM B treatment had the lightest ($P < 0.05$) L^* and least ($P < 0.05$) red a^* values in comparison to all other treatments, while all other treatments were similar ($P > 0.05$) for both traits. However, the bloom time allowed for more separation among treatments in the perceived subjective color. The COM B chops scored lower ($P < 0.05$) in color than all other treatments other than COM A, while PRE E scored higher ($P < 0.05$) than all other treatments other than PRE D. As was observed in the loin data, PRE A and PRE E had the highest ($P < 0.05$) marbling scores compared to all other treatments.

Table 2 presents the differences between WBSF, SSF, cook loss, purge loss, pH, and IMF. All treatments differed by no more than 0.7% IMF, indicating minimal variation; however, PRE E had a higher ($P < 0.05$) fat content in comparison to all treatments other than PRE A and PRE C ($P > 0.05$). Additionally, COM B had the lowest ($P < 0.05$) pH followed by PRE A, while the other brands were similar ($P > 0.05$), with all treatments within 0.2 pH units. Next, the PRE A, PRE C, and PRE D chops had the least ($P < 0.05$) purge loss compared to all other treatments. However, all purge loss percentages were less than 2.5%, indicating only a minimal loss of purge for all treatments. Moreover, the PRE E chops had the lowest ($P < 0.05$) cooking loss percentage compared to all treatments other than COM A. Additionally, the drip loss data aligned with the color data as COM B had the highest ($P < 0.05$) drip loss percentage compared to all other treatments.

While WBSF and SSF are both measures of tenderness, they have notable differences in protocols which could lead to differing results. Both measures were included in the current study to better understand the differences in tenderness. For WBSF, PRE C had the highest shear values ($P < 0.05$) in comparison to all other treatments while PRE E resulted in lower ($P < 0.05$) WBSF values than all treatments other than PRE A and PRE B. The SSF values yielded slightly different results, but PRE C still had the highest shear value ($P < 0.05$), being tougher than all other treatments.

Table 3 presents the eating quality differences found by trained sensory panelists. Similar to the other quality data, few differences were found by the trained sensory panelists for most attributes. There were no differences ($P > 0.05$) found for the initial juiciness and sustained juiciness attributes among all treatments.

Table 2. Loin tenderness, cook loss, purge loss, pH, and IMF content attributes ($n = 30$/brand) of premium and commodity pork loin brands

Treatment	WBSF[1]	SSF[2]	Cook loss[3]	Purge loss[4]	Drip loss[5]	pH	IMF[6]
Premium A	2.2[cd]	9.7[c]	14.6[bc]	1.1[d]	1.6[bc]	5.5[b]	2.7[ab]
Premium B	2.2[cd]	9.3[c]	15.7[ab]	2.3[ab]	0.9[f]	5.6[a]	2.5[bc]
Premium C	2.6[a]	14.8[a]	16.9[a]	1.2[d]	1.8[ab]	5.6[a]	2.6[ab]
Premium D	2.2[cd]	10.5[c]	14.9[bc]	1.2[d]	1.5[cd]	5.6[a]	2.4[bc]
Premium E	2.1[d]	10.2[c]	13.2[d]	1.8[c]	1.4[de]	5.6[a]	2.9[a]
Commodity A	2.6[b]	12.3[b]	14.4[cd]	2.3[a]	1.3[e]	5.6[a]	2.2[c]
Commodity B	2.4[bc]	9.9[c]	16.9[a]	1.8[bc]	2.0[a]	5.4[c]	2.4[bc]
SE[7]	0.09	0.56	0.46	0.01	0.07	0.03	0.0
P value	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01

[a–f]Means within the same column without a common superscript differ ($P < 0.05$).

[1]Warner-Bratzler shear force (WBSF); kg.

[2]Slice shear force (SSF); kg.

[3]Cooking loss = 1 − (cooked weight/raw weight) × 100.

[4]Purge loss = [(unopened loin in bag weight − loin weight − bag weight)/loin and bag weight] x 100.

[5]Drip loss = (initial weight of core – weight of core after 48 h)/initial weight x 100.

[6]Percentage intramuscular fat (IMF) content.

[7]SE (largest) of the least-squares means.

Table 3. Least-squares means ($n = 30$/brand) of pork quality ratings[1] for premium and commodity pork loin brands

Treatment	Initial juiciness	Sustained juiciness	Myofibrillar tenderness	Connective tissue amount	Overall tenderness	Pork flavor intensity	Off-flavor intensity
Premium A	59.9	54.5	66.4[b]	2.8[b]	64.6[ab]	34.8	0.1
Premium B	58.7	53.7	65.8[bc]	2.8[b]	63.7[bc]	33.4	0.3
Premium C	56.1	51.0	58.5[d]	4.1[a]	55.9[d]	34.5	0.2
Premium D	58.7	53.6	65.2[bc]	2.9[b]	63.4[bc]	34.6	0.3
Premium E	59.5	54.7	70.0[a]	2.3[b]	68.2[a]	34.3	0.2
Commodity A	58.1	53.1	62.6[c]	2.8[b]	60.9[c]	34.4	0.2
Commodity B	57.5	52.2	64.3[bc]	2.7[b]	62.5[bc]	32.8	0.3
SE[2]	1.23	1.31	1.24	0.36	1.30	0.56	0.18
P value	0.36	0.41	<0.01	<0.01	<0.01	0.16	0.99

[a–c]Means within the same column without a common superscript differ ($P < 0.05$).

[1]Sensory scores: 0 = extremely dry/tough/none/extremely bland/no off-flavor; 50 = neither dry nor juicy/neither tough nor tender; 100 = extremely juicy/tender/abundant/extremely intense.

[2]SE (largest) of the least-squares means.

The similarities found within WBSF and SSF were consistent with the trained sensory panel data for myofibrillar and overall tenderness. For myofibrillar tenderness, PRE E was rated as the most tender ($P < 0.05$), while PRE C was rated the toughest ($P < 0.05$). Similarly, PRE C had the most ($P < 0.05$) connective tissue compared to all other treatments. For overall tenderness, PRE E was rated as more tender ($P < 0.05$) than all treatments other than PRE A, while PRE C was the toughest ($P < 0.05$) overall. There were no differences ($P > 0.05$) identified between any treatment for pork flavor intensity or off flavor intensity. Overall, the trained sensory panel data indicate there were not large differences in eating quality, other than in tenderness, in which PRE C was the toughest for all measures.

Discussion

The relationship between color, WHC, and pH are longstanding dogmas of meat science, with a higher pH leading to a greater WHC, less water reflectance, and thus a darker color (Hamm and Deatherage, 1960; Boler et al., 2010). Without set parameters for pork quality to be measured, quantifying pork quality has been challenging (Huff-Lonergan et al., 2002).

Correlation studies have demonstrated the presence of a relationship of pH within raw meat quality factors such as color, firmness, drip loss, and cooking loss (Huff-Lonergan et al., 2002). However, the carry-over of these traits and their relationship to eating quality have been less explored within pork. Color, pH, and marbling are some of the most important quality factors for qualification into premium pork programs, so understanding the relationship between raw meat quality and eating quality is pivotal.

Color has been a critical factor for pork quality and consumer purchasing habits (Topel et al., 1976; Boler et al., 2010). The pH and elicited color have a well-established relationship impacted by the distance from the isoelectric point and WHC (Hamm and Deatherage, 1960; Joo et al., 1995; Boler et al., 2010). The current work supports the well-studied relationship between color and pH (Hamm and Deatherage, 1960; Boler et al., 2010). The differences found in our study were consistent between the initial color, and bloomed color within the loins and chops. In general, COM B was found to have the palest color with one of the least red colors and the lowest pH, regardless of whether the whole loin or chop was evaluated. This finding supports the previous research evaluating the relationship between objective and subjective color, and pH, while also highlighting the consistency of pork quality from the whole loin and the chop. This helps justify the pork industry's current use of pork loin measures of color as indicative of the color of chops that will eventually be evaluated at the point-of-sale by consumers.

pH has been used as an indicator of pork quality, especially color, as it has been shown to have the highest correlation to pork color when taken 45 min after exsanguination (Boler et al., 2010). Even though color and pH are correlated due to the relationship with the WHC of meat as previously described (Boler et al., 2010), the relationship is weakened when only acceptable quality pork is considered and with increased quality (Joo et al., 1995). In the current study, COM B had the lowest color scores, drip loss percentage, and pH, but still had a pH of 5.4, and was still acceptable for eating quality. While these differences were not translated into decreased scores for tenderness, juiciness, cook loss, or WBSF, other studies have found stronger relationships between color and eating quality. A study in 2010 concluded pH and the relationship with color had the strongest impact on the overall liking, juiciness, tenderness, and flavor with a correlation of $r = -0.78$ (Moeller et al., 2010). Also, it has been indicated that the consumer's perception of juiciness increases as pork color becomes darker (Norman et al., 2003; Moeller et al., 2010). One such study grouped L^* values into 3 categories ranging from 45 to 65 and found the perceived juiciness and tenderness to increase with a decreasing L^*, but the WBSF was unaffected (Norman et al., 2003). However, a direct comparison with the current work is difficult due to the Norman et al. (2003) study using a D65 light source for color measurement compared to the A10 used in the current study. A similar study evaluated the impact of differing color scores and pH to sensory traits and reported no correlation for pork with pH values under 5.95 (Richardson et al., 2018). This suggests a certain magnitude of difference within color and pH is needed to increase or decrease eating quality. The results of our study may have differed if the included brands had had larger range in color scores or pH.

The focus on pork color as the primary indicator of quality was established due to limited differences in marbling found industry-wide for pork in comparison to beef, and due to color having the greatest impact the consumer's purchasing intent (Boler et al., 2010; Bohrer and Boler, 2017). The role that marbling plays in the overall pork eating experience is minimal, with any differences being tied back to the marbling percentage range used. In one study, a marbling range from 1% to 8% did not make an impact on the overall eating quality, especially tenderness (Rincker et al., 2008). Similarly, Honegger et al. (2019) found that regardless of the amount of marbling present, consumers rated the pork chops similar if all other variables were kept constant. However, within a range of 1% to 6% IMF, significant correlations were found for marbling and overall liking, juiciness, flavor, and tenderness, but there was not a difference among the marbling ranges for many of the sensory characteristics evaluated (Moeller et al., 2010). This range of IMF was not present in the current study. Our study had a range of 2.2% IMF to 2.9% IMF and a marbling score range of 1.8 to 3.2 which was not variable enough to produce differences in eating quality. It is noteworthy that the current study used 5 different premium pork products in which marbling was a specification for most. Within these programs, despite selecting for marbling, all had mean IMF percentages of under 3%. According to the Moeller et al. (2010) study, IMF percentages of close to double this would be required to produce eating quality differences. This indicates significant efforts would be needed by the pork industry to raise the IMF percentage to a level that would have a meaningful impact on eating quality. Our results show that even in these premium programs, marbling level is not sufficient enough to influence the palatability traits.

Even though there were differences in color, pH, and WHC measures, there were no differences in initial juiciness and sustained juiciness. Therefore, the magnitude of differences observed among treatments were not large enough to elicit a difference in the juiciness eating quality attributes. However, the trained panelists determined differences in myofibrillar tenderness, connective tissue amount, and overall tenderness. But the brand that fell short with the raw meat quality factors, COM B, was not rated as the toughest. Arkfeld et al. (2017) determined the variation in tenderness was dependent on animal variation followed by season and then production practices, which were mostly unknown in the current study. This disconnect between raw meat quality factors and eating quality is important for the industry to make decisions about branded program specifications.

Historically, branding or quality grades have been sufficient to lead consumers to a consistent eating experience. If a consumer sees a product labeled to be "premium" or a brand clearly marketed as higher than commodity, then it is their expectation to have a heightened eating experience (Wilfong et al., 2016; Harr et al., 2022). In the beef industry, this is clearly achieved through the means of quality grades, boxed beef programs, and other certifications that are familiar to the consumer (Tatum, 2015). The means of assigning differential value to a beef carcass with quality grades has driven the producers to aim for higher quality animals; however, the same cannot be said for the pork industry (Bohrer and Boler, 2017). Pork value is typically assigned on a grid system, providing no incentive for higher quality pork as long as it is acceptable (Bohrer and Boler, 2017). While branding and quality separation has a greater monetary advantage in beef, there is also a larger range in quality differences in comparison to other commodities such as pork or chicken. The pork industry has made significant genetic improvements on the economically important traits related to animal growth, nutrition, reproductive traits, etc., which have created a more uniform pork product than is seen in other livestock species (Sellier and Rothschild, 1991; Huff-Lonergan et al., 2002). However, a study from Arkfeld et al. (2017) evaluated overall variation within a population of pork carcasses and concluded variation within raw characteristics still exists but is minimal. This relative homogeneity of product makes segregating premium products from this mix more difficult, as the variation between the identified premium products and commodity products is limited. Additionally, segregation of products into premium programs versus commodity is not always full and complete. Many times, products that would meet the criteria for these premium programs may be included in the commodity mix. In this way, premium programs serve as a way to increase product consistency, whereas commodity products may have a greater amount of variation in quality traits due to the lack of criteria and sorting. It is unclear whether the commodity products in the current work would have qualified for any of the premium programs evaluated. However, our results highlight how, despite best efforts, premium pork products do not produce consistently better quality traits or eating quality than commodity products, which in part may be due to an overlap in product inclusion for each.

With quality differences in pork often having only a minimal impact on eating quality, many recent studies have shifted focus to the impact of different degrees of doneness on pork eating experience. Cooking to a lower degree of doneness results in a juicier, more tender product with higher overall consumer liking scores (Klehm et al., 2018; Overholt et al., 2018; Nethery et al., 2022). These data have been consistent enough to influence the National Pork Board to release an official recommendation to cook pork to 63°C (NPB, n.d.; Overholt et al., 2018). Rincker et al. (2008) conducted trained sensory panels using 3 end-point temperatures (62°C, 71°C, and 80°C) with 5 marbling ranges from 1.58% to 5.73% and found no interaction but that determined juiciness and tenderness scores decreased with increasing degree of doneness. Moeller et al. (2010) found the same relationship between varied marbling ranges and multiple degrees of doneness. Therefore, one of the easiest ways to improve the eating experience of pork may be to cook it the recommended lower degree of doneness.

Our study shows that while there was some variation within the raw meat quality attributes evaluated, these differences did not translate to differences in the eating quality. Overall, this study indicates as a pork industry, uniformity and consistency have been achieved on a very large scale and that segregation of pork based on quality traits does not directly impact eating quality.

Conclusions

While there were minimal differences in the raw pork quality data for color and marbling among the branded programs, it only loosely translated to differences in objective and subjective tenderness. This study indicates the observed marbling and color differences play only a small role in impacting juiciness, flavor, or even tenderness of pork. The current pork industry uses quality differences including color, pH, and marbling level to set standards to segregate products into different branded, premium products in order to help consumers make educated purchasing decisions; however, these differences might not be impactful to the consumer once on the plate. Based on the results of the current study, the improvements made in the pork industry have closed the gap between commodity and premium domestic brands, and this has resulted in a highly consistent product for consumers. Efforts by pork producers and processors have resulted in high quality pork that both is tender and produces satisfactory quality attributes, despite differences in brands or processors.

Literature Cited

AMSA. 2015. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. 2nd ed. American Meat Science Association, Champaign, IL.

Arkfeld, E. K., D. A. Morhauser, D. A. King, T. L. Wheeler, A. C. Dilger, S. D. Shackelford, and D. D. Boler. 2017. Characterization of variability in pork carcass composition and primal quality. J. Anim. Sci. 95:697–708. https://doi.org/10.2527/jas.2016.1097.

Bohrer, B., and D. Boler. 2017. Subjective pork quality evaluation may not be indicative of instrumental pork quality measurements on a study-to-study basis. The Professional Animal Scientist 33:530–540. https://doi.org/10.15232/pas.2017-01644.

Boler, D. D., A. C. Dilger, B. Bidner, S. Carr, J. Eggert, J. Day, M. Ellis, F. McKeith, and J. Killefer. 2010. Ultimate pH explains variation in pork quality traits. J. Muscle Foods 21:119–130. https://doi.org/10.1111/j.1745-4573.2009.00171.x.

Buhr, B. L. 2004. Case studies of direct marketing value-added pork products in a commodity market. Appl. Econ. Perspect. P. 26:266–279. https://doi.org/10.1111/j.1467-9353.2004.00175.x.

Cravens, K. S., and C. Guilding. 1999. Strategic brand valuation: A cross-functional perspective. Bus. Horizons 42:53–54. https://doi.org/10.1016/S0007-6813(99)80064-0.

Folch, J., M. Lees, and G. H. Sloane Stanley. 1957. A simple method for the isolation and purification of total lipids from animal tissues. J. Biol. Chem. 266:497–509.

Grunert, K. G., L. Bredahl, and K. Brunsø. 2004. Consumer perception of meat quality and implications for product development in the meat sector—A review. Meat Sci. 66:259–272. https://doi.org/10.1016/S0309-1740(03)00130-X.

Hamm, R., and F. E. Deatherage. 1960. Changes in hydration, solubility, and charges of muscle proteins during heating of meat. J. Food Sci. 25:587–610. https://doi.org/10.1111/j.1365-2621.1960.tb00004.x.

Harr, K. M., E. S. Beyer, K. J. Farmer, S. G. Davis, M. D. Chao, J. L. Vipham, M. D. Zumbaugh, and T. G. O'Quinn. 2022. Labeling terms and production claims influence consumers' palatability perceptions of ground beef. Meat Muscle Biol. 6. https://doi.org/10.22175/mmb.15518.

Honegger, L. T., E. Richardson, E. D. Schunke, A. C. Dilger, and D. D. Boler. 2019. Final internal cooking temperature of pork chops influenced consumer eating experience more than visual color and marbling or ultimate pH. J. Anim. Sci. 97:2460–2467. https://doi.org/10.1093/jas/skz117.

Huff-Lonergan, E., T. J. Baas, M. Malek, J. C. Dekkers, K. Prusa, and M. Rothschild. 2002. Correlations among selected pork quality traits. J. Anim. Sci. 80:617–627. https://doi.org/10.2527/2002.803617x.

Joo, S. T., R. Kauffman, B. C. KIM, and C. J. KIM. 1995. The relationship between color and water-holding capacity in postrigor porcine longissimus muscle. J. Muscle Foods 6:211–226. https://doi.org/10.1111/j.1745-4573.1995.tb00568.x.

King, D. A., M. C. Hunt, S. Barbut, J. R. Claus, D. P. Cornforth, P. Joseph, Y. H. B. Kim, G. Lindahl, R. A. Mancini, M. N. Nair, K. J. Merok, A. Milkowski, A. Mohan, F. Pohlman, R. Ramanathan, C. R. Raines, M. Seyfert, O. Sørheim, S. P. Suman, and M. Weber. 2023. American Meat Science Association guidelines for meat color measurement. Meat Muscle Biol. 6:12473, 1–81. https://doi.org/10.22175/mmb.12473.

Klehm, B., D. King, A. Dilger, S. Shackelford, and D. Boler. 2018. Effect of packaging type during postmortem aging and degree of doneness on pork chop sensory traits of loins selected to vary in color and marbling. J. Anim. Sci. 96:1736–1744. https://doi.org/10.1093/jas/sky084.

Lammers, P., D. Stender, and M. Honeyman. 2007. Niche pork production. Iowa State University. https://smallfarms.oregonstate.edu/sites/agscid7/files/information.pdf.

Martinez, S. W., and K. D. Zering. 2004. Pork quality and the role of market organization. USDA-ERS Agricultural Economics Report.

Moeller, S., R. Miller, K. Edwards, H. Zerby, K. Logan, T. Aldredge, C. Stahl, M. Boggess, and J. Box-Steffensmeier. 2010. Consumer perceptions of pork eating quality as affected by pork quality attributes and end-point cooked temperature. Meat Sci. 84:14–22. https://doi.org/10.1016/j.meatsci.2009.06.023.

Nethery, T. N., D. D. Boler, B. N. Harsh, and A. C. Dilger. 2022. Relationship between inherent cooking rate and Warner-Bratzler shear force of pork chops cooked to two degrees of doneness. Foods 11:131. https://doi.org/10.3390/foods11010131.

Norman, J., E. Berg, H. Heymann, and C. Lorenzen. 2003. Pork loin color relative to sensory and instrumental tenderness and consumer acceptance. Meat Sci. 65:927–933. https://doi.org/10.1016/S0309-1740(02)00310-8.

NPB (National Pork Board) and Pork Checkoff. 2021. The Other White Meat. https://live.porkcheckoff.org/pork-branding/pork-brands/the-other-white-meat-brand. (Accessed 3 March 2022).

NPB (National Pork Board). n.d. Pork cooking temperature. https://pork.org/pork-cooking-temperature/. (Accessed 30 Sep 2023).

OECD. 2023. Meat consumption. https://data.oecd.org/agroutput/meat-consumption.htm. (Accessed 30 Sep 2023).

Office of the United States Trade Representative. 2019. Provisions of the U.S.-Japan Trade Agreement Pork and Pork Products. https://ustr.gov/about-us/policy-offices/press-office/fact-sheets/2019/october/provisions-of-the-us-japan-trade-agreement-pork. (Accessed 30 Sep 2023).

Overholt, M., B. Klehm, D. King, A. Dilger, S. Shackelfod, and D. Boler. 2018. Ability of early postmortem traits to predict sensory quality of pork loin chops may depend on degree-of-doneness. Meat Muscle Biol. 2. https://doi.org/10.221751/rmc2018.097.

Pork Checkoff. 2021. U.S. Pork Exports. https://www.porkcheckoff.org/markets/us-pork-exports/#:~:text=In%202021%2C%20exports%20accounted%20for,for%20every%20U.S.%20hog%20marketed. (Accessed 30 Sep 2023).

Rice, E. A., A. B. Lerner, B. A. Olson, L. L. Prill, L. N. Drey, H. E. Price, J. E. Lowell, B. N. Harsh, K. E. Barkley, L. T. Honegger, E. Richardson, J. C. Woodworth, J. M. Gonzalez, M. D. Tokach, J. M. DeRouchey, S. S. Dritz, R. D. Goodband, M. W. Allerson, B. Fields, S. D. Shackelford, D. A. King, T. L. Wheeler, A. C. Dilger, D. D. Boler, and T. G. O'Quinn. 2019. Effects of increased pork hot carcass weights. II: Loin quality characteristics and palatability ratings. Meat Muscle Biol. 3:447–456. https://doi.org/10.22175/mmb2019.07.0027.

Richardson, E. L., B. Fields, A. C. Dilger, and D. D. Boler. 2018. The effects of ultimate pH and color on sensory traits of pork loin chops cooked to a medium-rare degree of doneness. J. Anim. Sci. 96:3768–3776. https://doi.org/10.1093/jas/sky258.

Rincker, P., J. Killefer, M. Ellis, M. Brewer, and F. McKeith. 2008. Intramuscular fat content has little influence on the eating quality of fresh pork loin chops. J. Anim. Sci. 86:730–737. https://doi.org/10.2527/jas.2007-0490.

Sellier, P., and M. F. Rothschild. 1991. Breed identification and development in pigs. In: K. Maijala, editor, World animal science: Genetic resources of pig, sheep and goat. Elsevier Science Publishers, Amsterdam, The Netherlands. pp. 125–143.

Shackelford, S. D., T. L. Wheeler, and M. Koohmaraie. 1999. Evaluation of slice shear force as an objective method of assessing beef longissimus tenderness. J. Anim. Sci. 77:2693–2699. https://doi.org/10.2527/1999.77102693x.

Tatum, J. D. 2015. Recent trends: Beef quality, value and price. Colorado State University, Fort Collins, CO. pp. 1–14. https://www.beefcentral.com/wp-content/uploads/2016/01/Recent-Trends-Beef-Quality-Value-and-Price-12-19-15-J.-Daryl-Tatumrevised.pdf.

Tokach, M. D., B. D. Goodband, and T. G. O'Quinn. 2016. Performance-enhancing technologies in swine production. Animal Frontiers 6:15–21. https://doi.org/10.2527/af.2016-0039.

Topel, D. G., J. A. Miller, P. J. Berger, R. E. Rust, F. C. Parrish Jr., and K. Ono. 1976. Palatbility and visual acceptance of dark, normal, and pale colored porcine M. Longissimus. J. Food Sci. 41:628–630. https://doi.org/10.1111/j.1365-2621.1976.tb00685.x.

Towers, L. 2016. Pork meat quality: Understanding industry measurements and guidelines. https://www.thepigsite.com/articles/pork-meat-quality-understanding-industry-measurements-and guidelines. (Accessed 30 Sep 2023).

USDA. 1985. United States Standards for Grades of Pork Carcasses. https://www.ams.usda.gov/sites/default/files/media/Pork_Standard%5B1%5D.pdf.

USDA. 2023. AskUSDA. https://ask.usda.gov/s/article/What-is-the-most-consumed-meat-in-the-world#:~:text=According%20to%20the%20United%20Nations,goats%2Fsheep%20(5%25).

Wilfong, A. K., K. V. Ognoskie, J. M. Gonzalez, T. A. Houser, E. A. E. Boyle, J. A. Unruh, and T. G. O'Quinn. 2016. Determination of the effect of branding on consumer palatability ratings of beef strip loin steaks. Meat Sci. 112:114. https://doi.org/10.1016/j.meatsci.2015.08.036.

Willson, H. E., H. R. de Oliveira, A. P. Schinckel, D. Grossi, and L. F. Brito. 2020. Estimation of genetic parameters for pork quality, novel carcass, primal-cut and growth traits in Duroc pigs. Animals 10:25. https://doi.org/10.3390/ani10050779.