Final internal cooking temperature of pork chops influenced consumer eating experience more than visual color and marbling or ultimate pH

Lauren T. Honegger, Elaine Richardson, Emily D. Schunke, Anna C. Dilger, and Dustin D. Boler¹

Department of Animal Sciences, University of Illinois, Urbana, IL 61801

ABSTRACT: The objective was to determine the effect of “quality grade” (combination of visual color and marbling) or ultimate pH on consumer eating experience of pork chops cooked to different final internal temperatures. The hypothesis was that consumers would rate a greater percentage of pork chops as acceptable when graded “choice,” had a greater ultimate pH, or when cooked to 63 °C compared with chops graded “standard,” had a lesser ultimate pH, or when cooked to 71 or 82 °C. Consumers (264 total) were served chops in 1 of 2 experiments. Chops in Exp. 1 were classified as “choice” when NPPC visual color score ≥ 3 and visual marbling score was ≥ 2 or “standard” when NPPC scores did not meet the qualifications for “choice” and were cooked to either 63 or 71 °C. Chops in Exp. 2 were categorized as high pH (5.88 to 6.23) or low pH (5.36 to 5.56) and cooked to 63, 71, or 82 °C. Chops were cooked with a sous-vide device (ANOVA Precision Cooker, Anova Applied Electronics, San Francisco, CA) in a water bath. Consumers used a 9-point Likert-type score

system where scores 1 through 3 were considered not tender, not juicy, not flavorful, or unacceptable. Scores 4 through 6 were considered neutral for tenderness, juiciness, flavor, and overall acceptability. Scores 7 through 9 were considered tender, juicy, flavorful, and acceptable. Data were organized as a percentage of responses and analyzed using the GLIMMIX procedure of SAS for both experiments with models including treatment (quality grade, ultimate pH, and final internal temperature) and all interactions. Quality grade did not affect ($P \geq 0.30$) consumer ratings for any sensory trait. More ($P < 0.01$) consumers rated chops with a high pH (36.07%) as juicy compared with chops with a low pH (24.29%), but pH category did not alter ($P \geq 0.13$) perceptions for tenderness, flavor, or overall acceptability. In both studies, a greater ($P < 0.001$) percentage of consumers rated chops cooked to 63 °C as acceptable compared with chops cooked to 71 °C. Therefore, internal cooking temperature has a greater impact on consumer eating experience than “quality grade” or ultimate pH.

Keywords: color, consumer preference, degree of doneness, marbling, pork, ultimate pH

© The Author(s) 2019. Published by Oxford University Press on behalf of the American Society of Animal Science. All rights reserved. For permissions, please e-mail: journals.permissions@oup.com.

J. Anim. Sci. 2019.97:2460–2467

doi: 10.1093/jas/skz117

INTRODUCTION

Consumers use visual color and marbling (intramuscular fat) as indicators of tenderness and juiciness when evaluating pork products for purchase (Wood et al., 2004; Lonergan et al., 2007). Because consumers value color and marbling

when making purchasing decisions, the United States Department of Agriculture (USDA) used NPPC visual color and marbling as criteria for a proposed quality grading system where darker chops with greater marbling were valued over lighter chops with less marbling (USDA, 2017). Further, it has long been accepted that lighter colored chops have a lesser ultimate pH and darker colored chops have a greater ultimate pH (Monin and Sellier, 1985). Ultimate pH of pork chops was positively correlated with visual color and

¹Corresponding author: dboler2@illinois.edu

Received February 15, 2019.

Accepted April 8, 2019.

sensory tenderness (Huff-Lonergan et al., 2002). Additionally, increasing ultimate pH of fresh pork chops cooked to 71 °C increased sensory tenderness and juiciness (Lonergan et al., 2007) and cooking chops to 63 °C increased sensory tenderness scores (Richardson et al., 2018). Rincker et al. (2008) reported an improvement in sensory tenderness of pork chops cooked to 62 °C compared with chops cooked to 71 or 80 °C. Because of this, and because safety is not compromised, the USDA reduced the recommended endpoint temperature of pork muscle cuts, in 2011, from 71 to 63 °C as a means of improving sensory traits and maintaining food safety. However, there are limited data on the effects of ultimate pH or the proposed quality grading system on consumer acceptability of pork chops cooked to the revised internal cooking temperature recommendations. Therefore, the objective was to determine the effect of “quality grade” (combination of visual color and marbling) or ultimate pH on consumer eating experience of pork chops cooked to different final internal temperatures. The hypothesis was that consumers would rate a greater percentage of pork chops as acceptable when graded “choice,” had a greater ultimate pH, or when cooked to 63 °C compared with chops that graded “standard,” had a lesser pH, or when cooked to 71 or 82 °C.

MATERIALS AND METHODS

Pigs from both experiments were slaughtered at commercial facilities under the supervision of the USDA Food Safety and Inspection Service. Boneless loins were purchased from those facilities and transported to the University of Illinois Meat Science Laboratory. Therefore, Institutional Animal Care and Use Committee approval was not obtained. Sensory procedures for all consumer evaluations were reviewed and approved by the University of Illinois Office for the Protection of Research Subjects.

Experiment 1

Loins used in Exp. 1 were from a commercial feeding trial that evaluated a feed additive intended to improve gut health (data not published). Pork quality measurements were conducted on 14-d-aged loins including: visual color, visual marbling, subjective firmness, instrumental color, and ultimate pH. There were no differences between treatments for any loin quality trait ($P \geq 0.23$). Therefore, dietary treatments were disregarded during the allocations of loins to treatments for sensory

evaluation. Loins were categorized using the previously proposed USDA quality grades based on NPPC visual color and marbling scores. Chops were classified as “choice” when NPPC visual color score was ≥ 3 and visual marbling score was ≥ 2 or “standard” when either NPPC color or marbling score minimums were not met (USDA, 2017). Candidate loins were targeted to have an ultimate pH range of 5.65 to 5.80 (category C as defined by Lonergan et al., 2007). Due to the number of loins available in each quality grade, the pH range was slightly altered to an ultimate pH range of 5.64 to 5.76. In total, 24 loins that graded “choice” and 24 loins that graded “standard” were selected for consumer sensory evaluation (Table 1). Loins were cut into 2.54 cm thick chops using a push-feed style Treif Puma slicer (Treif model 700 F; Treif, Oberlahr, Germany). Chops were vacuum packaged and stored at -20 °C until sensory evaluation. Two chops from each loin were randomly assigned to ending cooking temperatures of 63 or 71 °C.

Experiment 2

Loins used in Exp. 2 were from the same population of pigs described previously by Richardson et al. (2018). The objective of that experiment was to determine effects of ultimate pH and visual color on trained sensory panel traits of pork loin chops cooked to an internal temperature of 63 °C. Loins, described by Richardson et al. (2018), were sorted into different pH bins based on historical pH categories described by Lonergan et al. (2007): category A > 5.95 , category B ≥ 5.80 to 5.95, category C ≥ 5.65 to 5.80, category D ≥ 5.50 to 5.65, and category E < 5.50 . Loins were sorted according to the ultimate pH of the loin muscle assessed at 1-d postmortem. Loins were selected from categories A and B to represent the high pH treatment group and from categories D and E to represent the low pH treatment group. High pH loins had an ultimate pH range of 5.88 to 6.23 (Table 2). Low pH loins had an ultimate pH range of 5.36 to 5.56. Twenty-six loins were selected from the high pH treatment group and 26 loins were selected for the low pH treatment group. Loins were aged until 16-d postmortem and were then cut into 2.54 cm thick chops, vacuum-packaged, and stored at -20 °C until further analysis. Three chops from each loin were randomly assigned to 1 of 3 ending cooking temperatures: 63, 71, and 82 °C.

Consumer Sensory Panels

All consumer sensory panels were conducted at the University of Illinois Meat Science Laboratory. Flyers and e-mails were sent out through the

Table 1. Effects of proposed USDA quality grade categories on chop quality characteristics

	Quality grade ¹			
Item	Choice	Standard	SEM	<i>P</i> -value
Subjective evaluations ²				
Visual color	3.3	3.3	0.07	0.66
Visual marbling	2.4	1.4	0.07	<0.0001
Subjective firmness	2.8	2.5	0.16	0.36
Instrumental color ³				
Lightness, L*	50.60	50.71	0.64	0.91
Redness, a*	8.27	8.25	0.32	0.96
Yellowness, b*	3.00	2.80	0.20	0.50
Ultimate pH	5.70	5.70	0.01	0.92
Extractable lipid, %	2.62	1.52	0.14	<0.0001

¹Choice chops had visual color scores ≥ 3 and visual marbling scores ≥ 2 . Standard chops were those that did not meet the minimum criteria for either visual color or visual marbling.

²NPPC color using the 1999 standards, half point scale where 1 = visually palest and 6 = visually darkest; NPPC marbling using the 1999 standards where 1 = visually the least marbling and 6 = visually the most marbling; NPPC firmness using the 1991 standard where 1 = softest and 6 = firmest.

³L* measures darkness to lightness (greater L* indicates a lighter color), a* measures redness (greater a* value indicates a redder color), and b* measures yellowness (greater b* value indicates a more yellow color).

university to assemble a pool of consumers for both experiments. Willing participants were given a link to fill out an online survey informing investigators of their age, gender, race, and education level (Tables 3 and 4). Along with demographic information, time availability was recorded for each participant. Once the online survey closed, participants were assigned panels. Participants were only allowed to participate once on each experiment, but some consumers did participate on both experiments. Panels were scheduled during 7 evaluation days. Each day included seven 20-min sensory panels that used up to 6 panelists per sensory session. Frozen chops were placed into boxes according to their assigned serving day. Chops for both experiments were removed from the freezer 24 h prior to each panel. Water baths were warmed using an immersion heater sous-vide device (ANOVA Precision Cooker, Anova Applied Electronics, San Francisco, CA) and set to 63 or 71 °C for Exp. 1 and 63, 71, or 82 °C for Exp. 2. Chops were cooked using a sous-vide approach because the method is becoming increasingly more popular among consumers (Baldwin, 2012). An hour and a half before each panel started, chops were removed from the refrigerator (still in the vacuum-sealed bag) and placed into their assigned water bath. Water bath temperatures were monitored and adjusted when needed throughout the cooking process. Upon arrival, participants completed a waiver

Table 2. Effects of ultimate pH categories on 16 d loin quality characteristics

Item	Ultimate pH ¹		SEM	P-value
	High	Low		
Ultimate pH	6.00	5.52	0.02	<0.0001
Subjective evaluations ²				
Visual color	3.8	3.1	0.10	<0.0001
Visual marbling	2.8	2.2	0.14	<0.01
Subjective firmness	3.3	3.2	0.11	0.62
Instrumental color ³				
Lightness, L*	42.00	47.77	0.64	<0.0001
Redness, a*	9.05	9.52	0.19	0.08
Yellowness, b*	3.16	5.65	0.25	<0.0001

¹High ultimate pH range of 5.88 to 6.23, low ultimate pH ranged 5.36 to 5.56 measured on day 1 postmortem.

²NPPC color using the 1999 standards, half point scale where 1 = visually palest and 6 = visually darkest; NPPC marbling using the 1999 standards where 1 = visually the least marbling and 6 = visually the most marbling; NPPC firmness using the 1991 standard where 1 = softest and 6 = firmest.

³L* measures darkness to lightness (greater L* indicates a lighter color), a* measures redness (greater a* value indicates a redder color), and b* measures yellowness (greater b* value indicates a more yellow color).

form informing them of the task they agreed to complete. After forms were signed and all participants were present, a monitor welcomed the group. A brief instruction session preparing participants for the sensory panel included a description of the sensory booths and what they needed to do with the material they were provided and instructions familiarizing each panelist with the evaluation forms. Once all consumer participants arrived, packaged chops were removed from the water bath. Chops were removed from their packages and final internal temperatures were measured using a meat thermometer. Chops were then placed in a sample sizer and sliced into 1 cm $\times$ 1 cm $\times$ 2.54 cm samples. Two pieces from each chop were placed into a small plastic cups with a numbered lid.

Panelists were seated in a breadbox style sensory booth room under red light to mask color differences among the samples. Panelist was provided a writing utensil, napkin, water, unsalted crackers, and an empty cup for any non-swallowed samples. A 9-point Likert-type scoring system was used where 1 was extremely tough, extremely dry, extremely bland, and unacceptable, 5 was neutral for tenderness, juiciness, flavorful, and acceptability, and 9 was extremely tender, extremely juicy, extremely flavorful, and acceptable. For Exp. 1, each panelist was served 4 samples (Choice, 63 °C; Choice, 71 °C; Standard, 63 °C; Standard, 71 °C) in a randomized order. For Exp. 2, each panelist was

Table 3. Demographic summary of participating consumers ($n = 133$) evaluating the effects of a proposed USDA quality grade and degree of doneness

Characteristic	Response	Percentage of consumers
Age	18–25 yr old	12.8
	26–35 yr old	13.5
	36–55 yr old	42.9
	56–75 yr old	30.1
	76 yr old or older	0.8
Ethnic origin	Asian/Pacific Islander	10.5
	Black or African American	1.5
	Hispanic or Latino	0.8
	Other	3.8
	White	83.5
Gender	Female	55.6
	Male	44.4
Education level	Completed an advanced or graduate degree	42.9
	Some graduate school	12.0
	Completed an undergraduate degree	27.8
	Some college	15.0
	High school diploma	2.3

served 6 samples (High pH, 63 °C; High pH, 71 °C; High pH, 82 °C; Low pH, 63 °C; Low pH, 71 °C; Low pH, 82 °C) in a randomized order. Samples were served to panelists one at a time through a small door on each of the sensory booths. Once all samples were served and evaluated, panelist exited the booth and returned the evaluation forms to the monitor.

Statistical Analysis

Data from each panel were entered into Excel (Microsoft Office, 2016) for each of the panelists using the score they provided for each sample in regards to tenderness, juiciness, flavor, and overall acceptability. The scoring was sorted into three categories. Scores 1 through 3 were considered not tender, not juicy, not flavorful, or unacceptable. Scores 4 through 6 were considered neutral for tenderness, juiciness, flavor, and overall acceptability. Scores 7 through 9 were considered tender, juicy, flavorful, and acceptable. Each experiment was treated as an independent data set, but all data were analyzed using the GLIMMIX procedure of SAS (SAS Inst. Inc., Cary, NC). Experiment 1 was analyzed using a model that included quality grade, degree

Table 4. Demographic summary of participating consumers ($n = 131$) evaluating the effects of loin ultimate pH and degree of doneness

Characteristic	Response	Percentage of consumers
Age	18–25 yr old	10.7
	26–35 yr old	20.6
	36–55 yr old	35.9
	56–75 yr old	31.3
	76 yr old or older	1.5
Ethnic origin	Asian/Pacific Islander	10.7
	Black or African American	0.8
	Hispanic or Latino	3.1
	Other	2.3
	White	83.2
Gender	Female	50.4
	Male	49.6
Education level	Completed an advanced or graduate degree	38.2
	Some graduate school	14.5
	Completed an undergraduate degree	23.7
	Some college	22.9
	High school diploma	0.8

of doneness, and the interaction. Experiment 2 was analyzed using a model that included pH category, degree of doneness, and the interaction. Panel was a random variable for both experiments. No significant interactions were detected for any parameter for either experiment. Therefore, only main effects were reported. All means were separated using the PDIFF option and were considered significantly different at $P < 0.05$. Means represent the percentage of panelists that reported findings in each of the 3 scoring categories.

RESULTS

Experiment 1

Demographic summary data from Exp. 1 are provided (Table 3). White ethnic origin and ages between 36 and 55 yr old were the majority of consumers (83.5% and 42.9%, respectively). Completed an advanced or graduate degree was the most common education level among consumers (42.9%). Gender was slightly skewed toward female (55.6%) compared with males (44.4%).

Only one significant interaction ($P = 0.02$) between degree of doneness and quality grades for

consumer overall neutral acceptability was detected. There were no differences in the percentage of choice chops rated neutral but a greater percentage of consumers rated standard chops cooked to 71 °C as neutral compared with standard chops cooked to 63 °C ($P < 0.001$). Quality grade had no effect ($P \geq 0.26$) on tenderness, juiciness, flavor, or acceptability of cooked pork chops regardless of temperature (Table 5). A greater percentage ($P < 0.001$) of consumers rated chops cooked to 63 °C to be tender (61.27%), juicy (61.66%), and flavorful (32.87%) compared to chops cooked to 71 °C. Overall, 47.78% of consumers rated chops cooked to 63 °C to be acceptable ($P < 0.001$) compared with only 17.90% of consumer acceptability of chops cooked to 71 °C.

Experiment 2

Demographic summary data from Exp. 2 are provided (Table 4). The majority of consumers were of white ethnic origin (83.2%) and between the ages of 36 to 55 yr old (35.88%). Gender was nearly equally represented between males (49.6%) and females (50.4%). Completed an advanced or graduate degree was the most common education level among consumers (38.2%).

There were no interactions ($P \geq 0.19$) between ultimate pH and degree of doneness for

any consumer sensory trait (Table 6). A greater ($P < 0.01$) percentage of consumers rated chops with a high pH (36.07%) as juicy compared with the percentage of consumers that rated chops with a low pH (24.29%) as juicy (Table 6). Tenderness, flavor, and overall acceptability were not influenced ($P \geq 0.13$) by ultimate pH.

Nearly 9% (8.48%) of consumers reported chops cooked to 71 °C to be not tender compared with only 0.87% of consumers rating chops cooked to 63 °C as not tender. Conversely, 81.25% of consumers rated chops cooked to 63 °C as tender. Whereas, only 49.05% of consumers rated chops cooked to 71 °C as tender.

Nearly 20% (19.51%) of consumers reported chops cooked to 71 °C to be not juicy compared with only 3.06% of consumers rating chops cooked to 63 °C as not juicy. Conversely, 70.61% of consumers rated chops cooked to 63 °C as juicy. Whereas, only 24.41% of consumers rated chops cooked to 71 °C as juicy.

Nearly 20% (17.90%) of consumers reported chops cooked to 71 °C to be not flavorful compared with only 10.23% of consumers rating chops cooked to 63 °C as not flavorful. Conversely, 39.83% of consumers rated chops cooked to 63 °C as flavorful. Whereas, only 22.50% of consumers rated chops cooked to 71 °C as flavorful.

Table 5. Effects of degree of doneness (DOD) and proposed USDA quality grade on consumer sensory traits of pork chops^{1,2}

	Quality grade ³		Degree of doneness			P-value		
	Choice	Standard	63 °C	71 °C	SEM	Quality grade	DOD	Quality grade × DOD
Consumer tenderness								
Not tender	13.07	13.08	6.34	24.98	3.62	0.99	<0.001	0.40
Neutral	42.28	41.76	32.13	52.60	3.36	0.91	<0.01	0.08
Tender	38.59	39.60	61.27	20.66	4.53	0.83	<0.001	0.26
Consumer juiciness								
Not juicy	13.53	10.45	4.75	26.80	3.68	0.36	<0.001	0.30
Neutral	45.57	45.23	33.46	57.90	3.16	0.94	<0.001	0.79
Juicy	32.69	34.48	61.66	13.71	4.48	0.71	<0.001	0.93
Consumer flavor								
Not flavorful	22.92	18.80	15.68	27.03	3.28	0.26	<0.01	0.24
Neutral	52.24	55.63	50.73	57.12	3.15	0.44	0.15	0.79
Flavorful	23.66	22.30	32.87	15.37	3.29	0.72	<0.001	0.20
Overall acceptability								
Not acceptable	10.45	10.78	6.07	17.90	2.96	0.91	<0.001	0.22
Neutral	56.79	56.71	45.63	67.22	3.45	0.99	<0.001	0.02
Acceptable	27.79	27.54	47.78	13.77	4.06	0.96	<0.001	0.11

¹Values reported are a percentage of responses for each of the main effects.

²Consumers used a 9-point Likert-type score system where scores 1 through 3 were considered not tender, not juicy, not flavorful, or unacceptable. Scores 4 through 6 were considered neutral for tenderness, juiciness, flavor, and overall acceptability. Scores 7 through 9 were considered tender, juicy, flavorful, and acceptable.

³Choice chops had visual color scores ≥ 3 and visual marbling scores ≥ 2 . Standard chops were those that did not meet the minimum criteria for either visual color or visual marbling.

Table 6. Effects of degree of doneness (DOD) and ultimate pH on consumer sensory traits of pork chops^{1,2}

	Ultimate pH ³		Degree of doneness				P-value		
	High	Low	63 °C	71 °C	82 °C	SEM	pH	DOD	pH × DOD
Consumer tenderness									
Not tender	4.28	6.32	0.87 ^c	8.48 ^b	17.00 ^a	3.16	0.36	<0.001	0.87
Neutral	34.80	36.06	18.89 ^c	40.87 ^b	50.64 ^a	3.67	0.73	<0.001	0.50
Tender	56.46	52.81	81.25 ^a	49.05 ^b	29.52 ^c	4.64	0.37	<0.001	0.42
Consumer juiciness									
Not juicy	14.17	16.99	3.06 ^c	19.51 ^b	44.82 ^a	5.11	0.41	<0.001	0.26
Neutral	38.45	41.81	27.11 ^b	51.19 ^a	43.52 ^a	3.33	0.35	<0.01	0.19
Juicy	36.07	24.29	70.61 ^a	24.41 ^b	9.03 ^c	4.91	<0.01	<0.001	0.93
Consumer flavor									
Not flavorful	18.82	16.10	10.23 ^c	17.90 ^b	27.40 ^a	4.08	0.33	<0.01	0.45
Neutral	54.17	52.64	47.87	56.34	55.96	3.41	0.67	0.10	0.52
Flavorful	21.15	26.07	39.83 ^a	22.50 ^b	13.15 ^c	4.59	0.13	<0.001	0.44
Overall acceptability									
Not acceptable	8.49	9.98	2.77 ^c	9.59 ^b	25.68 ^a	4.18	0.53	<0.001	0.96
Neutral	48.16	50.06	35.74 ^b	57.14 ^a	54.79 ^a	3.67	0.61	<0.001	0.93
Acceptable	36.44	31.87	61.82 ^a	30.61 ^b	16.27 ^c	4.62	0.23	<0.001	0.95

^{a,b}Least square means within a row among main effects lacking a common superscript differ ($P < 0.05$).

¹Values reported are a percentage of responses for each of the main effects.

²Consumers used a 9-point Likert-type score system where scores 1 through 3 were considered not tender, not juicy, not flavorful, or unacceptable. Scores 4 through 6 were considered neutral for tenderness, juiciness, flavor, and overall acceptability. Scores 7 through 9 were considered tender, juicy, flavorful, and acceptable.

³High ultimate pH ranged from 5.88 to 6.23, low ultimate pH ranged from 5.36 to 5.56.

Nearly 10% (9.59%) of consumers reported chops cooked to 71 °C to be not acceptable compared with only 2.77% of consumers rating chops cooked to 63 °C as not acceptable. Conversely, 61.82% of consumers rated chops cooked to 63 °C as acceptable. Whereas, only 30.61% of consumers rated chops cooked to 71 °C as acceptable.

DISCUSSION

Fresh color and visual marbling are used as indicators of tenderness and juiciness by consumers when they evaluate pork products for purchase (Wood et al., 2004; Lonergan et al., 2007). Because of this, the USDA proposed a quality grading system using NPPC visual color and marbling scores (USDA, 2017) as a means of providing consumers a tool to aid in selection of fresh pork chops. However, for this grading system to be successful, color and marbling need to be associated with a positive eating experience. To date, nearly all reports evaluating the relationships between color and marbling with eating experience have used trained sensory panelists rather than consumers. Further, only limited data are available to determine consumers' preferences when chops were cooked to 63 °C rather than 71 °C.

For the present study, chops were assigned to 1 of 2 quality grade categories, choice or standard.

Consumers were unable to detect sensory tenderness, juiciness, or flavor differences between the quality grades. These results are consistent with a previous trained sensory panel study that cooked chops to 63 °C. Wilson et al. (2017) reported that extractable lipid and instrumental color were independently poor predictors of sensory traits in pork loin chops cooked to 63 °C. Additionally, Wilson et al. (2017) reported trained sensory panelist was unable to detect differences in tenderness or juiciness among chops categorized into "quality grades" of high, medium, and low quality grading system. If the classification system of Wilson et al. (2017) was used on the loins of the present study, then the standard loins would be "low quality" and the choice loins "medium quality."

Color and marbling are most often used as indicators of eating quality, but recent results do not support these relationships. Lowell et al. (2017) reported cook loss percentage ($r \leq |0.22|$) and instrumental tenderness ($r \leq |0.26|$) were not correlated with instrumental color or visual color when chops were cooked to 68 °C. No instrumental or visual color parameters were moderately or strongly correlated with instrumental tenderness or cook loss in chops cooked to a range of 63 to 71 °C as described in Harsh et al. (2018). Rincker et al. (2008) reported a positive, but weak, relationship between sensory traits and marbling that only accounted for

13% of variation explained by those measurements with chops cooked to 71 °C.

In contrast to these results, [Cannata et al. \(2010\)](#) reported trained sensory panelist rated chops with greater marbling (3.56%) as more juicy and tender compared to chops with less marbling (1.96%) of marbling when chops were cooked to 71 °C. Another study reported consumers rated chops with 3% to 3.5% extractable lipid content as more tender and juicy than chops with $\leq 1\%$ extractable lipid when chops were cooked to a 71 °C internal temperature ([Brewer et al., 2001](#)). In both studies described above, the extractable lipid levels of the “high” treatments were greater than the mean extractable lipid (2.62%) of the “choice” quality grade used in the present study. In fact, the amount of extractable lipid of the “high” treatment group would rate as “Prime” in the proposed quality grading system.

Though the hypothesis for the present study was that chops grading choice would rate more tender, juicy, flavorful, and overall more acceptable compared to standard chops, this was not the case. One explanation for this lack of difference in eating experience is the similar color of standard and choice chops in this study. Because both color and marbling requirements must be met for chops to be labeled choice, standard chops did meet the color requirement (NPPC color score of ≥ 3) but not the marbling requirement (NPPC marbling score of ≥ 2). This resulted in similar color scores and objective color readings between standard and choice chops. Future research should include prime, choice, select, and standard quality grades using the USDA proposed quality system. In today’s industry, finding a well-controlled population that ranges from prime to select quality grades might prove difficult but would provide good additional information to the present study.

An additional objective of the present study was to determine the influence of ultimate pH on consumer perceptions of pork chop sensory traits. Previously, ultimate pH of pork chops was positively correlated with visual color and sensory tenderness ([Huff-Lonergan et al., 2002](#)). Additionally, increasing ultimate pH of fresh pork chops increased sensory tenderness and juiciness of chops cooked to 71 °C ([Lonergan et al., 2007](#)). This is similar to the present study where a greater percentage of consumers rated the high pH treatment juicy compared to the low pH treatment. However, no other consumer sensory traits were different between the pH treatments. Results of the present study are similar to those of [Richardson et al.](#)

(2018) who reported no differences in sensory tenderness between chops of different ultimate pH when chops were cooked to 63 °C, until pH exceeded 5.95. Chops with ultimate pH greater than 5.95 were more tender than all other pH categories. However, consumers in the present study did not find pork chops from the “high” pH category to be more tender. In the present study, this “high” category included loins with ultimate pH ranging from 5.88 to 6.23, therefore not as extreme as the high pH loins in the previous study.

While consumers were not able to detect differences in tenderness between pH treatments or quality grades, they were able to detect differences in tenderness between chops cooked to different degrees of doneness. The USDA recently changed the final internal temperature to cook whole pork muscles from 71 to 63 °C ([FSIS, 2013](#)). The pork production industry has changed over the years to an indoor commercial setting eliminating the risk of contamination via *Trichinella spiralis*, allowing for a lower endpoint cooking temperature ([Pyburn et al., 2005](#)). In this present study, both previously established and revised cooking temperatures were used to assess their effect on consumer sensory traits. Regardless of pH treatment or quality grade, consumers rated chops cooked to 63 °C more tender, juicy, flavorful, and overall acceptable compared to chops cooked to a higher degree of doneness. [Rincker et al. \(2008\)](#) reported, as final internal cooking temperature increases from 62 to 80 °C, trained sensory tenderness and juiciness decreases from 8.56 to 6.81 and 9.85 to 6.29, respectively. [Rincker et al. \(2008\)](#) also reported a linear relationship between consumer tenderness and juiciness scores and visual marbling score, in chops cooked to 71 °C. However, results from the present study indicate that it is the final internal temperature that impacts overall eating experience, not quality grade (visual color and visual marbling).

Public acceptance and application of the revised cooking temperature will require both time and education. According to focus groups conducted by [FSIS \(1998\)](#), consumers do not regularly use meat thermometers. Other methods such as the “eye ball” method, cooking until no red or pink is inside, or until juice or fluids run clear were among the reported methods used by consumers to check their meat. Focus groups also reported that they would use a meat thermometer if it would enhance the flavor or quality of the product they were preparing. Consumers need to be educated on the importance of the meat thermometer and the ideal temperature to cook whole pork muscles.

Font-i-Furnols and Guerrero (2014) explained that a consumer's behavior toward meat and meat products can be affected by three main factor categories: marketing, psychological, and sensory factors. Visual appearance (color and marbling) of the meat is a sensory factor that was discussed earlier. Additionally, psychological factors may include beliefs of meat that were formed by observations, information, or inferences can all influence consumer preferences (Font-i-Furnols and Guerrero, 2014). Education on proper cooking techniques and cooking temperatures of pork products, with the use of a meat thermometer, will help to ensure consumers have a positive eating experience and become a repeat consumer.

In conclusion, ultimate pH has little impact on consumer sensory traits except for juiciness which increases with increasing ultimate pH. A proposed quality grade system would not guarantee superior eating experience with higher quality grades. Additionally, a lower final internal temperature of whole pork muscles will improve tenderness, juiciness, flavor, and overall consumer acceptability. Overall, ultimate pH and "quality grades" did not impact consumer sensory traits of pork loin chops that cooked to 63 °C. Regardless of the visual color or marbling of a pork chop in the retail case, preparation of the chop by the consumer has a greater impact than the pork chop that is purchased.

LITERATURE CITED

- Baldwin, D. E. 2012. Sous vide cooking: a review. *Int. J. Gastron. Food Sci.* 1:15–30. doi:10.1016/j.ijgfs.2011.11.002
- Brewer, M. S., L. G. Zhu, and F. K. McKeith. 2001. Marbling effects on quality characteristics of pork loin chops: consumer purchase intent, visual and sensory characteristics. *Meat Sci.* 59:153–163. doi:10.1016/S0309-1740(01)00065-1
- Cannata, S., T. E. Engle, S. J. Moeller, H. N. Zerby, A. E. Radunz, M. D. Green, P. D. Bass, and K. E. Belk. 2010. Effect of visual marbling on sensory properties and quality traits of pork loin. *Meat Sci.* 85:428–434. doi:10.1016/j.meatsci.2010.02.011
- Font-i-Furnols, M., and L. Guerrero. 2014. Consumer preference, behavior and perception about meat and meat products: an overview. *Meat Sci.* 98:361–371. doi:10.1016/j.meatsci.2014.06.025
- Food Safety and Inspection Service (FSIS). 1998. Focus groups on barriers that limit consumers' use of thermometers when cooking meat and poultry products: phase on. U.S. Food and Drug Administration, FSIS, Washington, DC. <http://www.fsis.usda.gov/oa/topics/focusgp.pdf> (Accessed 21 December 2018.)
- Food Safety and Inspection Service (FSIS). 2013. Fresh pork from farm to table. https://www.fsis.usda.gov/wps/portal/fsis/topics/food-safety-education/get-answers/food-safety-fact-sheets/meat-preparation/fresh-pork-from-farm-to-table/CT_Index (Accessed 21 December 2018.)
- Harsh, B. N., D. D. Boler, S. D. Shackelford, and A. C. Dilger. 2018. Determining the relationship between early postmortem loin quality attributes and aged loin quality attributes using meta-analyses techniques. *J. Anim. Sci.* 96:3161–3172. doi:10.1093/jas/sky183
- Huff-Lonergan, E., T. J. Baas, M. Malek, J. C. M. Dekkers, K. Prusa, and M. F. Rothschild. 2002. Correlations among selected pork quality traits. *J. Anim. Sci.* 80:617–627. doi:10.2527/2002.803617x
- 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. *J. Anim. Sci.* 85:1074–1079. doi:10.2527/jas.2006-413
- Lowell, J. E., M. F. Overholt, B. N. Harsh, C. A. Stahl, A. C. Dilger, and D. D. Boler. 2017. Relationships among early postmortem loin quality and aged loin and pork chop quality characteristics between barrows and gilts. *Transl. Anim. Sci.* 1:607–619. doi:10.2527/tas2017.0074
- Monin, G., and P. Sellier. 1985. Pork of low technological quality with a normal rate of muscle pH fall in the immediate post-mortem period: the case of the Hampshire breed. *Meat Sci.* 13:49–63. doi:10.1016/S0309-1740(85)80004-8
- Pyburn, D. G., H. R. Gamble, E. A. Wagstrom, L. A. Anderson, and L. E. Miller. 2005. Trichinae certification in the United States pork industry. *Vet. Parasitol.* 132:179–183. doi:10.1016/j.vetpar.2005.05.051
- 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. doi:10.1093/jas/sky258
- 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. doi:10.2527/jas.2007-0490
- USDA. 2017. U.S. grade standards: pork carcasses. https://www.regulations.gov/document?D=AMS_FRDOC_0001-1640 (Accessed 12 January 2019.)
- Wilson, K. B., M. F. Overholt, C. M. Shull, C. Schwab, A. C. Dilger, and D. D. Boler. 2017. The effects of instrumental color and extractable lipid content on sensory characteristics of pork loin chops cooked to a medium-rare degree of doneness. *J. Anim. Sci.* 95:2052–2060. doi:10.2527/jas.2016.1313
- Wood, J. D., G. R. Nute, R. I. Richardson, F. M. Whittington, O. Southwood, G. Plastow, R. Mansbridge, N. da Costa, and K. C. Chang. 2004. Effects of breed, diet and muscle on fat deposition and eating quality in pigs. *Meat Sci.* 67:651–667. doi:10.1016/j.meatsci.2004.01.007