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Effects of Increased Pork Hot Carcass Weights. II: Loin Quality Characteristics and Palatability Ratings[1,2]

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Abstract: The objective of this study was to evaluate the effects of increased pork hot carcass weight on loin quality and palatability of top loin chops. Pork loins ($N = 200$) were collected from 4 different hot carcass weight groups: A light weight (LT; less than 111.8 kg), medium-light weight (MLT; 111.8 to 119.1 kg), medium-heavy weight (MHVY; 119.1 to 124.4), and a heavyweight group (HVY; 124.4 and greater). Following fabrication, chops were assigned to fat and moisture analysis, Warner-Bratzler shear force (WBSF), consumer sensory panels, or trained sensory panels. Chops from the HVY group were rated as more ($P < 0.05$) tender compared to chops from the LT carcasses. Additionally, chops from the HVY weight group had greater ($P < 0.05$) consumer overall like ratings compared to chops from both the LT and MLT groups. Carcass weight did not affect ($P > 0.05$) consumer flavor liking ratings. Hot carcass weight treatment did not contribute ($P > 0.05$) to the percentage of chops rated acceptable for flavor and overall liking. The greatest ($P < 0.05$) percentage of samples were rated acceptable for juiciness for chops from the HVY weight group, and the lowest ($P < 0.05$) percentage of acceptable ratings for tenderness were for chops from the LT weight group. Both initial and sustained juiciness from MHVY carcasses were rated as more ($P < 0.05$) juicy compared to chops from both MLT and LT carcasses by trained sensory panelists. Additionally, chops from the LT carcasses had the lowest ($P < 0.05$) myofibrillar tenderness ratings. Chops from MHVY and HVY carcasses were similar ($P > 0.05$), with greater ($P < 0.05$) overall tenderness ratings compared to chops from LT carcasses. These results indicate chops from heavier weight carcasses may have improved tenderness and juiciness compared to chops from lighter carcasses.

Keywords: consumer, heavy pigs, hot carcass weight, palatability, pork quality
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Introduction

The average hot carcass weight of pork carcasses in the United States has steadily increased year to year (USDA-NASS, 2019). With a continued increase of 0.59 kg/yr, the average hot carcass weight for market pigs in the United States could reach 118 kg by

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the year 2052 (USDA-NASS, 2019). To date, little research has evaluated the quality and eating characteristics of pork from these elevated carcass weights. It is unclear what the impact of increased carcass weight may be on pork quality and palatability traits.

In order for consumers to have a satisfactory eating experience, their expectations for tenderness, juiciness, and flavor must be met (O'Quinn et al., 2018). Tenderness has previously been reported to be the most crucial factor impacting pork palatability (Wood et al., 2004). Previous work that has evaluated pork quality and palatability traits of carcasses of differing weights has produced conflicting results (Cisneros et al., 1996; Beattie et al., 1999; Virgili et al., 2003; Harsh et al., 2017). Most of these studies were conducted with pigs with live weights that ranged from 90 to 130 kg. Currently, the average live market weight for pigs in the United States is about 128 kg, which makes it difficult to predict what will happen to pork quality as market weights continue to increase (USDA-NASS, 2019). Additionally, differences in animal genetics and study objectives limit the ability to draw meaningful conclusions from much of this past work evaluating heavy carcasses as it relates to the industry today.

As United States pork hot carcass weights continue to increase, it is unclear what the impact on tenderness, juiciness, and favor will be. Although studies have assessed the impact of hot carcass weight on pork quality, there is little research that exists that has evaluated the impact of increased hot carcass weights on consumer or trained panel palatability ratings (Wu et al., 2017). Therefore, the objective of this study was to determine the impact of increased hot carcass weights on pork tenderness, juiciness, and flavor as well as its impact on pork loin quality characteristics.

Materials and Methods

The Kansas State University (KSU) Institutional Review Board approved the procedures used in this study (IRB 7440.4, Nov. 2017).

Loin collection and fabrication

Details regarding the swine production procedures, the genetic line used, and pig marketing strategies for this study are described in detail by Lerner et al. (2018) and Rice et al. (2019). Briefly, pigs for this study were intentionally raised to reach heavy live weights exceeding normal industry standards. Following harvest, carcasses were grouped into 4 separate hot carcass weight categories for meat quality analyses. Harvest took place on 2 separate days at a commercial harvest facility. At harvest, carcasses were sorted by hot carcass weight into a light group (LT; under 111.8 kg), medium light group (MLT; 111.8 to 119.1 kg), medium heavy group (MHVY; 119.1 to 124.4 kg), and heavy group (HVY; greater than 124.4 kg). Carcasses were selected from these carcasses weight treatment groups without consideration of the pen spacing treatments evaluated by Lerner et al. (2018). Whole boneless pork loins (N = 200; Institutional Meat Purchase Specification #413; North American Meat Institute, 2014) were selected from random carcasses within each hot carcass weight treatment. A total of 25 loins from each weight group from each slaughter date were selected for use in the trial. Loins were then vacuum packaged and transported to the KSU Meat Laboratory for fabrication.

Prior to fabrication, loins were weighed in the package to obtain an initial weight and were then blotted dry and reweighed after unpackaging. Following opening, the vacuum bags for each loin were washed, dried, and weighed to use in the calculation of the percentage of purge lost during storage. Percentage of purge loss was calculated using the equation [1 – unpackaged weight/(packaged weight – dry bag weight)]×100. Loins were then allowed a 30 min period of oxygenation prior to measurement of instrumental color readings. Instrumental lightness (L*), redness (a*), and yellowness (b*) measurements were taken using Hunter Lab Miniscan spectrophotometer (Illuminant A, 2.54-cm aperture, 10° observer, Hunter Lab Associates Laboratory, Reston, VA). Three readings were taken on each loin, with one at the anterior, one in the middle, and one on the posterior end of the ventral side of each loin and averaged to obtain a single measurement. Additionally, a trained KSU research team member assessed each loin for visual color and marbling according to the National Pork Producers Council pork quality standards (National Pork Producers Council, 1999). The research team member assessed color and marbling scores as an average for the entire length of the ventral side of the loin. Also, 3 pH readings were taken using a pH meter (HI 99163, Hanna Instruments, Smithfield, RI) at the anterior, middle, and posterior sections of the loin and averaged to obtain a single value for each loin. Loins were then cut immediately posterior to the *M. spinalis dorsi* and the posterior end of the loin was used for all analyses. Details regarding chop fabrication, thickness allocation, and consumer visual evaluation are provided by Rice et al. (2019). A 2.54 cm thick chop was cut immediately posterior to the *M spinalis dorsi* and assigned to 24 and 48 h drip loss percentage test-

Table 1. Definitions and selected references for pork palatability traits evaluated by trained sensory panelists

Attribute	Definition	Reference[1]
Initial juiciness	Juiciness level within the first 1 to 3 chews	Non-enhanced boneless pork top loin chop cooked[2] to 71°C = 55
Sustained juiciness	Juiciness level maintained by the sample throughout the chewing process	Non-enhanced boneless pork top loin chop cooked[2] to 71°C = 50
Myofibrillar tenderness	The tenderness of myofibrillar tissue excluding connective tissue	Non-enhanced boneless pork top loin chop cooked[2] to 71°C = 65
Connective tissue	The amount of connective tissue within the sample	Non-enhanced boneless pork top loin chop cooked[2] to 71°C = 2
Overall tenderness	The overall tenderness of the sample	Non-enhanced boneless pork top loin chop cooked[2] to 71°C = 65
Pork flavor intensity[3]	Amount of pork flavor identity in the sample	Non-enhanced boneless pork top loin chop cooked[2] to 71°C = 30

[1] Reference point on 0 to 100 point scale.

[2] Chops grilled on clam-shell style grills (Cuisinart Griddler Deluxe, Model GR-150, East Windsor, NJ) with surface temperature of 177°C.

[3] Adapted from pork identity lexicon described by Chu (2015).

ing. Following consumer visual evaluation, one 2.54 cm thick chop from each loin was assigned to consumer sensory evaluation and one 3.18 cm chop was assigned to Warner-Bratzler shear force analysis (WBSF). An additional 2.54 cm thick chop was assigned to trained sensory evaluation and one 1.27 cm chop was assigned to raw fat and moisture analysis. Chops were then vacuum packaged and frozen at –40°C after a 10-d postmortem aging period.

Consumer sensory evaluation

Consumers ($N = 197$) used for sensory evaluation were recruited from Manhattan, KS, and the surrounding areas and monetarily rewarded for their participation in the study. Sensory panels took place in a lecture style classroom at KSU in groups of 24 panelists. Chops were thawed at 2 to 4°C for 24 h prior to consumer sensory panels. Chops were cooked on clamshell style grills (Cuisinart Griddler Deluxe, Model GR-150, East Windsor, NJ) and removed from the heat with the internal temperature rising to a peak internal temperature of 71°C. Temperature was monitored using a Thermapen thermometer (Mk4; ThermoWorks, American Forks, UT), with the probe remaining in the chop throughout cooking. All external fat was removed and only the *longissimus* muscle was cut into 2.54-cm thick × 1-cm × 1-cm cuboids, and 2 cuboids were immediately served to each panelist for evaluation. Each panelist was provided with a napkin, plastic fork, expectorant cup, and apple juice, water, and unsalted crackers to use as palate cleansers.

Each panelist evaluated 8 samples (2/treatment) in a random order and recorded ratings on an electronic tablet (Model 5709 HP Stream 7; Hewlett-Packard, Palo Alto, CA) using a digital survey (Version 2417833; Qualtrics Software, Provo UT). Panelists evaluated each sample for juiciness, tenderness, flavor like, and overall like on continuous line scales anchored at both ends and the midpoint with: 0 = extremely dry, extremely tough, and dislike extremely; 50 = neither dry nor juicy, neither tough nor tender, neither like nor dislike flavor, and neither like nor dislike overall; and 100 = extremely juicy, extremely tender, and like extremely. Consumers were also asked to rate each palatability trait as either acceptable or unacceptable with yes/no questions. Additionally, consumers were asked to rate the quality they perceived each sample, as either unsatisfactory, everyday quality, better than everyday quality, or premium quality.

Trained sensory analysis

Panelists were trained using protocols described by the American Meat Science Association (AMSA) sensory guidelines (AMSA, 2016). Six sensory trainings were held in the 2 wk prior to starting panels. In each training session, panelists were trained by evaluating pork top loin chop samples cooked to different degrees of doneness (rare [60°C], medium [71°C], and well-done [77°C], and very well-done [82°C]) to represent different juiciness, tenderness, and flavor levels. The references for the scales used for all traits evaluated are presented in Table 1.

Chops were thawed at 2 to 4°C for 24 h prior to sensory panel evaluation. Chops were prepared using the same procedures previously described for consumer sensory panels. Each panel consisted of 8 members with a total of 25 panel sessions used in the study. A warmup sample was provided for panel calibration at the beginning of each panel. Each panelist evaluated 8 samples (2 from each treatment) in a random order on an electronic tablet (Model 5709 HP Steam 7; Hewlett-Packard, Palo Alto, CA) with an online digital survey (Version 2417833; Qualtrics Software, Provo, UT). Each sample was evaluated for initial juiciness, sustained juiciness, myofibrillar tenderness, overall tenderness, pork flavor intensity, and off flavor intensity on continuous line scales. Anchors were set at 0 to 100 with a midpoint at 50. The 0-anchor was labeled as: extremely dry, extremely tough, no connective tissue, extremely bland. The 50-anchor was labeled as: neither juicy nor dry, neither tough nor tender, and neither like nor dislike. The 100-anchor was labeled as: extremely juicy, extremely tender, abundant connective tissue, intense flavor. For off-flavor, panelists had a "not applicable" option if no off flavors were detected. Panelists were served in individual booths under red, low intensity (110 lx), incandescent lights. Each panelist was provided deionized water, cut apple slices, and unsalted crackers to use as palate cleansers, as well as an expectorant cup and napkin.

Warner-Bratzler shear force analysis

Warner Bratzler shear force analyses were performed using protocols described by the AMSA in the Research Guidelines for Cookery, Sensory Evaluation, and Instrumental Tenderness Measurements of Meat (AMSA, 2016). Chops were cooked as previously described for sensory analyses. Chops were chilled for 24 h at 2 to 4°C following cooking. Six cores (1.27-cm diameter) were removed parallel to the muscle fiber orientation and sheared perpendicular to the muscle fiber orientation. Shears were performed using an INSTRON Model 5569 (Instron, Canton, MA) with a crosshead speed of 250 mm/min and a load cell of 100 kg. The 6 values were averaged to determine the average peak force (kg) for each chop.

Fat and moisture content and drip loss analysis

Chops assigned to fat and moisture analyses were thawed at 2 to 4°C for 24 h prior to homogenization. All subcutaneous fat and accessory muscles were removed and the *longissimus* muscle was diced into smaller pieces before being immersed in liquid nitrogen. When completely frozen, samples were then homogenized (Model S1BL32; Waring Products Division; Hartford, CT) and stored in VWR Sterile Sample Bags (VWR International LLC, Pittsburgh, PA) in a –80°C freezer until analysis. Using protocols described by Folch et al. (1957), total intramuscular fat was measured using a chloroform:methanol extraction method. Analyses were performed in duplicates. Total moisture was measured using the methods described by the AOAC (1995).

Drip loss was determined using the EZ-driploss protocol described by Correa et al. (2007). Immediately after fabrication, two 2.54-cm cores were removed from each chop, weighed and place in an air tight container and stored at 2 to 4°C. Cores were reweighed at 24 and 48 h. Drip loss percentage was determined by the formula: [(initial weight – 24 or 48-hr weight)/initial weight × 100].

Statistical analysis

Statistical analyses were performed using the PROC GLIMMIX procedure of SAS (SAS Version 9.4; SAS Inst. Inc., Cary, NC). Loin was used as the experimental unit and the 4 weight groups as treatments. Sensory panel data were evaluated as a completely randomized design with panel session included as a random effect. A model with binomial error distribution was used for all acceptability data. For all analyses, α was set at 0.05 and the Kenward-Roger approximation was used. Consumer demographic information was summarized using PROC FREQ.

Results

Loin quality

The loin quality characteristics (WBSF, loin weight, purge loss percentage, pH, moisture percentage, fat percentage, 24 and 48 h drip loss percentage, and cook loss percentage) are presented in Table 2. With the exception of loin weight, there were no differences ($P > 0.05$) found for any of the loin quality traits among the weight treatment groups. As hot carcass weight increased from LT to HVY there was an increase ($P < 0.05$) in loin weight (LT < MLT < MHVY < HVY). Additionally, there were no differences ($P > 0.05$) in WBSF tenderness values as hot carcass weights increased.

Loin instrumental color, visual color, and visual marbling scores are displayed in Table 3. There were no differences ($P > 0.05$) among weight groups for L*, a*, and b* color values. Additionally, there were no differences ($P > 0.05$) in subjective color and marbling scores of the loins among the weight groups.

Consumer demographics

The consumer demographics for the 197 participants of the sensory portion are presented in Table 4. Of the consumers used for this study, just over half where female (54.8%) and were predominately Caucasian (72.1%). Additionally, 60.4% were between the ages of 20 to 39 yr, while 17.3% were over the age of 50 yr. Furthermore, 60.9% of consumers were college graduates, and 63.8% had an annual household income of more than \$50,000 per year. A majority of consumers

Table 2. Least squares means for loin ($N = 200$) quality characteristics of 4 weight groupings of pork hot carcasses

Carcass weight[1]	Loin weight, kg.	Purge loss[2], %	pH	Warner-Bratzler Shear Force, kg	Moisture, %	Fat, %	24 h drip loss[3], %	48 h drip loss[4], %	Cook loss[5], %
LT	4.0^{a}	2.7	5.7	2.7	73.1	2.7	1.3	1.8	16.2
MLT	4.5^{b}	2.6	5.7	2.6	75.4	2.8	1.1	1.5	15.8
MHVY	4.6^{c}	2.6	5.7	2.5	73.1	2.6	1.1	1.5	15.5
HVY	4.9^{d}	2.4	5.7	2.5	73.1	2.8	1.1	1.5	15.0
SEM[6]	0.13	0.16	0.01	0.06	0.26	0.14	0.07	0.10	0.57
P-value	< 0.01	0.48	0.35	0.22	0.17	0.60	0.05	0.10	0.56

[a–d] Least squares means in the same column without a common superscript differ ($P < 0.05$).

[1] Carcass weight groups: LT = under 111.8 kg, MLT = 111.8 to 119.1 kg, MHVY = 119.1 to 124.4 kg, and HVY = 124.4 kg and above.

[2] Purge loss percentage = [1 – loin weight/(packaged loin weight – dry bag weight)].

[3] 24 h drip loss percentage = [(initial weight – 24 h weight)/initial weight × 100].

[4] 48 h drip loss percentage = [(initial weight – 48 h weight)/initial weight × 100].

[5] Cook loss percentage = [(raw weight – cooked weight)/raw weight]

[6] SEM (largest) of the least squares means in the same column.

indicated that flavor (59.4%) was the most important palatability factor when consuming fresh pork, and 32% indicated that package price/kg was the most important factor when purchasing fresh pork followed by chop color (20.1%) and chop size (19.1%). The preferred degree of doneness when consuming pork was well done (35.5%) followed by medium well (28.9%) and medium (20.8%), and most consumers consumed pork 1 to 5 times per week (71.2%).

Consumer sensory evaluation

Consumer sensory ratings (Table 5) indicated there were no differences ($P > 0.05$) among the 4 hot carcass weight treatment groups for juiciness or flavor ratings. However, juiciness tended ($P = 0.05$) to differ among treatments with increased carcass weight being juicier than the lower carcass weights. Consumers did find differences among the treatment groups for tenderness ratings and overall like ratings. Consumers ratings indicated that carcasses from the HVY, MHVY, MLT hot carcass weight groups were all similar ($P > 0.05$) and more tender ($P < 0.05$) than carcasses from the LT hot carcass weight group. Additionally, consumer overall like ratings indicated that consumers preferred ($P < 0.05$) chops from carcasses in the HVY hot carcass weight treatment group compared to chops from both the MLT and LT hot carcass weight groups.

Consumers were also asked to indicate if each sample was acceptable for each palatability trait (Table 6). There were no differences ($P > 0.05$) among hot carcass weight treatments for the percentage of consumers who indicated samples were acceptable for flavor, and overall acceptability. There were differences ($P < 0.05$) for the percentage of consumers who rated the samples acceptable for juiciness and tenderness. A greater ($P < 0.05$) percentage of consumers rated chops from HVY weight carcasses as acceptable for juiciness compared to all other hot carcass weight treatments, which were similar ($P > 0.05$). Chops from the LT hot carcass weight treatment had the lowest ($P < 0.05$) percentage of consumers that rated them as acceptable for tenderness compared to all other weight treatments, which were similar ($P > 0.05$).

Finally, consumers indicated the quality at which they perceived each sample (Table 7). There were no differences ($P > 0.05$) in the percentage of chops from each hot carcass weight group that consumers perceived as everyday quality, better than everyday quality, or premium quality. Consumers perceived fewer ($P < 0.05$) chops from the HVY weight group as unsatisfactory compared to chops from the LT and MHVY hot carcass weight groups.

Trained sensory evaluation

The results for trained sensory panel evaluations are presented in Table 8. For both initial and sustained juiciness, trained panelists indicated chops from the MHVY group were juicier ($P > 0.05$) than chops from the MLT and LT carcasses, with chops from heavy carcasses being intermediate. Trained panelists rated chops from HVY, MHVY, and MLT carcasses similar ($P > 0.05$) for myofibrillar tenderness, and greater ($P < 0.05$) than chops from LT weight carcasses. Additionally, HVY and MHVY carcasses were similar ($P > 0.05$) for overall tenderness, and were more tender ($P < 0.05$) compared to carcasses from the LT hot carcass weight group. Trained sensory panelists did not detect any differences

Table 3. Instrumental and visual color and marbling scores for the ventral surface of pork loins ($N = 200$) of 4 weight groupings of pork hot carcasses

Carcass weight[1]	L*[2]	a*[3]	b*[4]	Color score[5]	Marbling score[6]
LT	59.1	16.6	14.4	4.2	2.3
MLT	59.5	16.4	14.3	4.3	2.4
MHVY	58.7	16.9	14.5	4.2	2.2
HVY	58.1	16.6	14.4	4.4	2.4
SEM[7]	0.33	0.18	0.16	0.10	0.08
P-value	0.38	0.27	0.82	0.29	0.26

[1] Carcass weight groups: LT = under 111.8 kg, MLT = 111.8 to 119.1 kg, MHVY = 119.1 to 124.4 kg, and HVY = 124.4 kg and above.

[2] L* (lightness; 0 = black and 100 = white).

[3] a* (redness; –60 = green and 60 = red).

[4] b* (yellowness; –60 blue and 60 = yellow).

[5] Color score: 1 to 6 according to the National Pork Board color standards.

[6] Marbling Score: 1 to 10 according to the National Pork Board marbling standards.

[7] SEM (largest) of the least squares means in the same column.

($P > 0.05$) among the 4 hot carcass weight groups for connective tissue amount or flavor characteristics.

Discussion

As market weights for pigs in the United States continue to increase, it is important that the lean quality of heavier carcasses not decrease and negatively impact pork eating quality and product functionality (Harsh et al., 2017). Although there have been studies that have assessed the impact of increasing hot carcass weight on pork quality, very few have used hot carcass weights as great as those used in the current study within swine genetic lines commonly used in the United States.

The effect of increased hot carcass weight on loin quality

In our study, increased hot carcass weight did not affect ultimate loin pH. Accordingly, there were also no visual or instrumental color differences found. Our results are consistent with the results for ultimate pH presented by Martin et al. (1980) and Beattie et al. (1999), where the authors found no differences among carcasses of increasing weight groups. This is contradictory to the data presented by Harsh et al. (2017), where the authors reported a decrease in ultimate pH as hot carcass weight increased. However, it is important to note that the design of the experiment performed by Harsh et al. (2017) was different than the current work in the sense that the authors performed regression analysis to predict the change in pork quality characteristics as hot carcass weight increased. When using the regression [$y = 5.86 - 0.0018$ (hot carcass weight, kg); $R^2 = 0.0123$] provided by Harsh et al. (2017) with the weights used in the current study (111.8 to 124.4 kg), the pH average would be expected to be 5.7 to 5.6, which is consistent with the pH values of the current study, where we found no differences among weight treatments.

Additionally, other studies (Virgili et al., 2003; Harsh et al., 2017) have reported a lower L* value as hot carcass weight increased, indicative of a darker lean color, which is not consistent with the current study. It is important to note that the study by Virgili et al. (2003) used an Italian pig breed that is not consistent with current commercial genetics in the United States. Harsh et al. (2017) stated that even though differences in both ultimate pH and 20 d L* values were found in their study, hot carcass weight only accounted for a small percentage ($R^2 = 0.0123$ and $R^2 = 0.0098$) of the variability and concluded the observed differences were likely attributed to other factors. The similar L* and a* values between weight treatments in the present study do support results reported Park and Lee (2011), in which no differences in L* values were reported as hot carcass weight increased. However, they utilized pigs at market weights that were lighter (116.2 to 133.5 kg live market weight) than the pigs in the current work.

Multiple studies have reported increasing a* values resulting in a redder product as hot carcass weight increased (Latorre et al., 2004; Durkin et al., 2012; Harsh et al., 2017). The studies by both Latorre et al. (2004) and Durkin et al. (2012) were conducted with the intent of testing the effect of sex and increased slaughter weights on carcass quality traits. Both studies utilized pigs that were lighter (116 to 133 kg and 120 to > 170 kg live market weight) than the pigs used in the current study. Additionally, Harsh et al. (2017) only reported this increase with Day 1 a* color readings, with a small amount of variation ($R2 = 0.0071$) associated with hot carcass weight. Moreover, those authors did not find any differences in Day 20 a* values with carcasses that ranged from 53.2 to 129 kg (Harsh et al., 2017). Their Day 20 results are similar to the current study where there were no differences in a* values as hot carcass weight increased.

The visual color measurements and instrumental color measurements in the current study were consistent, as both indicated there were no color differences among weight groups. Correa et al. (2006) reported similar results, although the pigs used in their study had live weights that ranged from 107 to 125 kg and were signifi-

Table 4. Demographic characteristics of consumers (*N* = 197) who participated in consumer sensory panels

Characteristic	Response	Percentage of consumers
Gender	Male	45.2
	Female	54.8
Household size	1 person	17.8
	2 people	32.5
	3 people	14.7
	4 people	17.8
	5 people	7.6
	6 people	9.6
Marital status	Married	50.3
	Single	49.7
Age	Under 20	9.6
	20 to 29	35.5
	30 to 39	24.9
	40 to 49	12.7
	50 to 59	6.6
	Over 60	10.7
Ethnic origin	African-American	6.6
	Asian	4.6
	Caucasian/white	72.1
	Hispanic	7.6
	Mixed race	6.1
	Native American	0.5
	Other	2.5
Income	Under $25,000	17.6
	$25,000 to $34,999	7.8
	$35,000 to $49,999	10.9
	$50,000 to $74,999	18.7
	$75,000 to $99,999	14.5
	$100,000 to $149,999	18.7
	$150,000 to $199,999	6.7
	> $199,999	5.2
Education level	High school graduate	11.2
	Some college/technical school	27.9
	College graduate	34.0
	Post college graduate	26.9
Most important palatability trait when consuming pork	Tenderness	18.3
	Juiciness	22.3
	Flavor	59.4
Most important visual trait when purchasing fresh pork	Chop color	20.1
	Chop firmness	3.6
	Chop size	19.1
	Marbling	10.3
	Price/kg	32.0
	Total price	13.9
	Other	1.0
Preferred degree of doneness when consuming pork	Rare	0.0
	Medium rare	10.2
	Medium	20.8
	Medium well	28.9
	Well done	35.5
	Very well done	4.6
Weekly pork consumption	1 to 5 times	71.2
	6 to 10 times	22.5
	11 or more times	6.3

Table 5. Least squares means for consumer ($N = 197$) palatability ratings[1] of pork top loin chops of varying hot carcass weight groups

Carcass weight[2]	Juiciness rating	Tenderness rating	Flavor rating	Overall like rating
LT	57.3	55.5^{b}	58.5	58.7^{b}
MLT	59.9	60.4^{a}	59.6	60.3^{b}
MHVY	59.8	60.8^{a}	61.3	61.2^{ab}
HVY	63.7	64.4^{a}	62.5	64.7^{a}
SEM[3]	1.75	1.75	1.51	1.55
P-value	0.05	< 0.01	0.10	0.02

[a,b]Least squares means in the same column without a common superscript differ ($P < 0.05$).

[1]Sensory scores: 0 = extremely dry/tough/dislike flavor/dislike overall; 100 = extremely juicy/tender/like flavor/overall like.

[2]Carcass weight groups: LT = under 111.8 kg, MLT = 111.8 to 119.1 kg, MHVY = 119.1 to 124.4 kg, and HVY = 124.4 kg and above.

[3]SEM (largest) of the least squares means in the same column.

Table 6. Least squares means for the percentage of consumers ($N = 197$) who indicated the chop was acceptable for juiciness, tenderness, flavor, and overall for top loin chops from varying hot carcass weight groups

Carcass weight[1]	Juiciness acceptability	Tenderness acceptability	Flavor acceptability	Overall acceptability
LT	78.5^{b}	80.2^{b}	82.9	80.2
MLT	80.7^{b}	85.7^{a}	83.7	83.6
MHVY	80.1^{b}	86.8^{a}	82.9	83.5
HVY	86.1^{a}	89.7^{a}	85.1	87.4
SEM[2]	2.28	2.26	2.28	2.37
P-value	0.04	< 0.01	0.81	0.07

[a,b]Least squares means in the same column without a common superscript differ ($P < 0.05$).

[1]Carcass weight groups: LT = under 111.8 kg, MLT = 111.8 to 119.1 kg, MHVY = 119.1 to 124.4 kg, and HVY = 124.4 kg and above.

[2]SEM (largest) of the least squares means in the same column.

cantly lighter than the pigs used for the current study. In contrast, Harsh et al. (2017) reported an improvement in visual color scores statistically, but again acknowledged the regression lines they calculated only slightly differed from 0, with an $R^2 = 0.0016$ for their Day 1 color scores and an $R^2 = 0.0123$ for their Day 20 color scores.

The findings in our study for visual marbling scores are consistent with previous studies that evaluated loin marbling of increasing hot carcass weights. Correa et al. (2006) and Harsh et al. (2017) reported no significant differences in visual marbling scores as hot carcass weight increased. This is consistent with the intramuscular fat percentages for the current study which did not differ among hot carcass weight treatments. This is similar to Correa et al. (2006) who also reported no differences in intramuscular fat percentages as market weight increased from 107 to 125 kg. Conversely, Cisneros et al. (1996) evaluated pigs with live weights ranging from 100 to 160 kg and reported an increase of approximately 0.3% intramuscular fat for every 10 kg increase in live weight.

With there being no differences in pH and intramuscular fat among weight treatments in our study, as would be expected, both drip loss percentages and cook loss percentages did not differ among weight treatments. Our drip loss means are contradictory to results published in previous studies (Cisneros et al., 1996; Virgili et al., 2003; Park and Lee, 2011). Both Cisneros et al. (1996) and Park and Lee (2011) reported that as hot carcass weight increased, there was an increase in drip loss percentage, while Virgili et al. (2003) reported a decrease in drip loss percentage with increased carcass weights.

There were also no differences among carcass weight groups for Warner-Bratzler shear force tenderness in the current study. These results are similar to data reported by both Beattie et al. (1999) and Latorre et al. (2004), even though the carcasses in both studies did not reach the weights of the current study. Harsh et al. (2017) reported a decrease in slice shear force tenderness values as hot carcass weights increased, which is similar to the sensory analysis portion of the current study. But, Martin et al. (1980) observed an opposite effect with an increase in WBSF values with increased live slaughter weight. Similarly, Cisneros et al. (1996) reported differences in tenderness and juiciness as live market weight increased; however, they found no significance with their linear regression for WBSF values and live market weight.

Table 7. Least squares means for the percentage of samples rated as unsatisfactory, every day, better than every day, and premium quality by consumers ($N = 197$) of pork top loin chops from carcasses of varying hot carcass weights

Carcass weight[1]	Unsatisfactory	Everyday quality	Better than every day	Premium
LT	17.3^{a}	48.7	25.6	7.6
MLT	14.1^{ab}	48.3	26.6	10.1
MHVY	16.3^{a}	47.1	24.3	11.2
HVY	10.6^{b}	46.8	30.0	11.8
SEM[2]	2.11	2.56	2.38	1.77
P-value	0.04	0.94	0.34	0.20

[a,b]Least squares means in the same column without a common superscript differ ($P < 0.05$).

[1]Carcass weight groups: LT = under 111.8 kg, MLT = 111.8 to 119.1 kg, MHVY = 119.1 to 124.4 kg, and HVY = 124.4 kg and above.

[2]SEM (largest) of the least squares means in the same column.

Table 8. Least squares means for trained sensory panel ratings[1] for pork top loin chops of varying hot carcass weight groups

Carcass weight[2]	Initial juiciness	Sustained juiciness	Myofibrillar tenderness	Connective tissue	Overall tenderness	Pork flavor	Off flavor
LT	53.3^{b}	45.3^{b}	63.6^{b}	4.3	62.7^{b}	31.5	5.2
MLT	52.9^{b}	45.1^{b}	66.8^{a}	4.2	65.3^{ab}	31.7	7.3
MHVY	57.1^{a}	49.9^{a}	68.9^{a}	4.0	67.5^{a}	32.1	4.9
HVY	55.8^{ab}	48.0^{ab}	68.7^{a}	3.9	67.3^{a}	31.5	3.1
SEM[3]	1.24	1.32	1.11	0.38	1.14	0.52	1.93
P- value	0.03	0.02	< 0.01	0.81	< 0.01	0.62	0.38

[a,b] Least squares means in 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] Carcass weight groups: LT = under 111.8 kg, MLT = 111.8 to 119.1 kg, MHVY = 119.1 to 124.4 kg, and HVY = 124.4 kg and above.

[3] SEM (largest) of the least squares means in the same column.

The effect of increased hot carcass weight on palatability ratings

Although no differences were found among loin quality traits in the current study, tenderness improved as hot carcass weight increased for both consumer and trained sensory panelists. This is contradictory to the WBSF data, as no differences were found among hot carcass weight treatment groups. To date, few studies have assessed the sensory attributes of pork carcasses as hot carcass weight increases, and the few that have, have produced conflicting results (Cisneros et al., 1996; Huff-Lonergan et al., 2002; Park and Lee, 2011). Similar to our study, Huff-Lonergan et al. (2002) observed positive responses for juiciness ($r = 0.09$) as well as off flavor ($r = 0.14$) as carcass weight increased. The authors attributed these responses to both increased fat deposition as hot carcass weight increased as well as increased polyunsaturated fatty acid concentrations in the fat (Huff-Lonergan et al., 2002). However, in the current study, there were no differences in intramuscular fat deposition as hot carcass weight increased and similar results were observed. In another study, Park and Lee (2011) reported an increase in off flavor of raw pork as slaughter weight increased; however, these results were not found in the cooked pork analysis in that study nor in the current study. The third study, Cisneros et al. (1996), reported contradictory results to the current work, where those authors reported a decrease in juiciness and tenderness of 0.1 and 0.04% for every 10 kg increase in market weight. However, similar to the current study, the authors reported no effect for WBSF values (Cisneros et al., 1996).

In the current work, consumer panelists gave greater ratings for tenderness, juiciness, and overall like to carcasses from the heavier weight groups. Similar results were found by trained sensory panelists, indicating improved juiciness and tenderness for heavier carcasses. The improved palatability ratings for tenderness and juiciness observed in the current study may be the result of different chilling rates at harvest. Larger carcasses require a greater amount of chilling time and thus result in a higher muscle temperature as the carcass undergoes the biochemical processes related to the conversion of muscle to meat (Dolezal et al., 1982). Thus, lighter weight carcasses could undergo a greater amount of cold-shortening and result in a tougher product (Jeremiah et al., 1992; Huff-Lonergan and Page, 2001). This difference in chilling rate and the associated impact on sarcomere length could potentially be the cause of the observed differences in tenderness in the current study.

The results of this study indicate that pork quality traits and eating quality will not be negatively impacted by increasing hot carcass weights to those heavier than currently found in the US pork industry. As the trend toward heavier carcass weight continue, pork chops from these carcasses will be as palatable, if not more acceptable, than pork chops from lighter weight carcasses.

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