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Meat quality: consumer demands

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CONSISTENCY IN MEAT QUALITY

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Background

Establishing an understanding of meat eating quality and consistency with consumer acceptability has been an area of high interest to meat scientists since the inception of the meat science discipline. Most meat science research programs have a component of their research agenda that examines some aspects of meat quality. Meat quality research may include examination of factors that affect meat quality and/or how to control or improve meat quality and consistency. The objective of this paper is to discuss the most recent research that has been conducted in the U.S. that has examined the variation in beef and pork meat quality and the relationship between beef and pork meat quality characteristics and consumer acceptance. To address the overall objective, the quality traits traditionally defined within each species will be discussed, then recent research on the variability in these quality traits will be presented, and lastly the current research on the relationship between these quality traits and consumer acceptance will be discussed.

Beef

Quality Traits. Quality traits can be categorized into two areas: 1) visual quality characteristics; and 2) eating quality characteristics, also referred to as meat palatability. While additional quality characteristics could be argued, these two general categories tend to be the most commonly examined and reported in the scientific literature. Additionally, attributes within these two categories have been used to establish relationships between quality traits and consumer acceptance. Visual beef quality characteristics have been defined as lean color, firmness, marbling and the amount of visible subcutaneous and intermuscular fat. For grass-fed or short-fed beef, fat color and the incidence of two-toned or heat-ring also may be included in visual quality characteristics. As the incidence of too much visible fat, injection site blemishes or blood splash are obvious quality defects, they will not be addressed as their incidence obviously needs to be reduced, controlled and eliminated. Beef eating characteristics have been defined as juiciness, tenderness and flavor. It has been generally accepted that while the visual quality characteristics are by themselves direct measures of beef quality; they also have indirect association with eating quality. For example, increased level of marbling has been related to increased juiciness and improved flavor attributes and tenderness in red meat (Savell and Cross, 1988).

As eating quality traits can not be directly measured on either the live animal, the beef carcasses, or the fresh beef subprimal or cut, visual quality characteristics have been used to predict eating quality. In the U.S., the USDA Beef Quality Grading system has been used since the early 1900's as the measure of beef quality. The purpose of the USDA Beef Grading system is to segment the large, heterogeneous beef carcass population into more homogeneous groups based on expected palatability (USDA, 1989). These grades are based on animal age (physiological age based on bone ossification and lean color) and the amount of intramuscular fat or marbling. The issue of how effective quality grades or marbling are in segmenting beef into meat palatability or eating quality categories has been extensively discussed. As U.S. beef grades are tied to beef palatability, the palatability of beef at different quality grade levels would expectantly differ. Beef palatability attributes of juiciness, tenderness and flavor can be measured by either trained sensory panelists or by consumer sensory panelists. Most meat science research has concentrated on the use of trained sensory panelists to quantatate beef palatability traits and then to use these data to determine if the USDA Quality Grading system is accurately segmenting beef. However, the issue of the strength of the relationship between trained sensory evaluation of meat palatability and consumer acceptability also needs to be addressed. Establishing relationships between consumer sensory acceptability and/or trained sensory evaluation is inherently difficult. Consumer sensory responses are highly variable and this inherent variability makes it statistically difficult to establish strong relationships. Additionally, the segmentation of beef consumers into a limited number of groups based on a narrow range of descriptors or attributes may limit the full understanding of consumer preferences. Consumers are highly variable and may or may not easily segment into defined consumer preference categories.

Color is included as a component of the USDA Beef Quality Grading system. Mainly, dark colored lean is penalized and a carcass with dark colored lean has to have a higher amount of marbling to qualify for the same quality grade as a carcass with lighter colored lean (USDA, 1989). Color is used to account for animal age and dark colored lean due to long-term pre-slaughter stress. Darker colored lean due to increased animal age has been associated with increased toughness and increased intensity of some beef flavor attributes (serumy, livery, metallic, cowy, musty and beef lean flavors). Dark colored lean due to long-term pre-slaughter stress has been associated with changes in beef flavor (serumy, livery, metallic, cowy, musty and beef lean flavors attributes), but in young animals, it has been associated with increased juiciness and subsequent improvements in beef tenderness.

Variability in Quality Traits. Two programs have been implemented in the U.S. to audit or survey the U.S. beef population for variation in beef quality. First, the National Beef Quality Audit programs, conducted in 1991 (Lorenzen et al., 1993), 1995 (Boleman et al., 1998) and in 2000 (study in progress), have or are being conducted to serve as bench marks for assessing the impact of producer practices on carcass values and to identify producer steps to improve the quality and consistency of beef. Second, the National Beef Tenderness Surveys in 1990 (Morgan et al., 1991) and in 1999 (Brooks et al., 2000) were conducted to determine the sensory tenderness scores and Warner-Bratzler shear force values from a representative cross-section of U.S. retail cuts varying in USDA quality grade and subprimal source. These two programs will be used to ascertain if variability exists in beef quality.

The National Beef Quality Audit in 1991 reported that the beef quality grade distribution was 2.3% Prime, 52.7% Choice, 36.9% Select, 7.6% Standard, .2% Commercial, and .3% Cutter and Canner. In 1995, the beef quality grade distribution was 1.6% Prime, 48.2% Choice, 46.5% Select, and 3.8% Standard. Boleman et al. (1998) concluded that overall, marbling scores had decreased from 1991 to 1995, but there were fewer carcasses in the USDA Standard grade. An audit currently is in progress to determine if changes in USDA quality grades have occurred in the last 5 years.

What does this say about consistency in meat quality? This indicates that for the U.S. beef population, variability in meat quality has been reduced as the number of USDA Standard carcasses have decreased and a higher percentage of the beef carcasses fall within the USDA Choice and Select quality grades. However, there also has been a slight decrease in beef quality with the shift of a higher percentage of beef carcasses into the USDA Select grade. The Beef Quality Audits are a method of assessing variability in the U.S. beef population for slaughter floor and cooler quality characteristics, but these audits do not include direct measures of beef palatability. Two Beef Tenderness Surveys have been conducted to sample the U.S. beef population for variation in beef tenderness as measured by trained meat descriptive attribute sensory panelists (Morgan et al., 1991) or consumer sensory evaluation panelists (Brooks et al., 2000) and by Warner-Bratzler shear force values. While these surveys included other aspects of meat palatability, the major emphasis was to examine meat tenderness.

Warner-Bratzler shear force values decreased in beef retail cuts from the ribeye, top loin and top sirloin from 1990 to 1998 (Table 1). Similarly, reductions in Warner-Bratzler shear force values decreased for the clod, chuck roll, top round, and eye of round cuts within the same time frame. Cooking methods differed between the two studies as the clod, chuck roll, top round, eye of round and bottom round steaks were braised in 1990 and they were broiled in 1998. Therefore, cooking method may explain some of the differences between the two studies for these cuts. The bottom round steak was the only cut that did not decrease in Warner-Bratzler shear force between the two studies. In summary, this study showed a general reduction in overall tenderness and in the variation of beef tenderness for all cuts, except for the bottom round steak. *Is this variation acceptable or are additional improvements in beef tenderness needed?* When data were examined to determine the percentage of cuts that exceeded the 50% confidence levels (cuts with Warner-Bratzler shear force values > 4.6 kg) and 68% confidence levels (cuts with Warner-Bratzler shear force values > 3.9 kg), a high percentage of the cuts from the chuck roll, top round, eye of round, and bottom round were outside these levels (5.2, 15.4, 26.6 and 52.6 for the 50% confidence level and 25.2, 39.6, 55.9 and 68.0% for the 68% confidence level, respectively). These results indicate that improvements in tenderness for cuts from the round are needed.

Variation in postmortem aging at the retail meat case was reported by the Beef Tenderness Surveys and most likely contributes to variation in beef tenderness. Morgan et al. (1991) and Brooks et al. (2000) reported that the average aging time for beef in the retail meat case was 19 days, but aging time varied from 3 to 90 days in 1990 and aging time varied from 2 to 61 days in the retail meat case in 1998. In 1998, Brooks et al. (2000) calculated that 26.7, 41.9, 31.1, 30.2, 28.6, 45.5, 31.0, and 39.0% and 34.1% of chuck, boneless ribeye, bone-in ribeye, short loins, boneless strip loins, bone-in strip loins, top sirloin butts, and round retail cuts, respectively, were aged less than 14 days. On average, 34.1% of retail cuts were aged less than 14 days. Brooks et al. (2000) found that average aging time for beef merchandized in the foodservice segment was 32 days and aging time ranged from 5 to 67 days. They reported that 20.0, 33.3, 26.7 and 0% of boneless ribeyes, bone-in ribeyes, boness strip loins and top sirloin foodservice cuts, respectively, were aged less than 14 days and on average, 19.4% of foodservice cuts were aged less than 14 days. These results indicate that beef is sufficiently aged to reduce variability in beef tenderness; however, beef that is aged less than 7 to 10 days most likely contributes to increased beef tenderness variation.

Relationship of Quality Traits to Consumer Acceptance. Based on the previous discussion, some variation in beef quality exists, but there is some question as to if this variation is contributing to decreased consumer acceptance. To understand the relationship of tenderness and the USDA Beef Quality Grading system, especially for USDA Choice and Select (the grade levels where most of the U.S. beef is contained), an in-home consumer sensory study was conducted. The Beef Customer Satisfaction Study was conducted in 1993 and 1994 and Neely et al. (1998), Lorenzen et al. (1999), Savell et al. (1999) and Neely et al. (1999) reported results. This study utilized moderate-to-heavy beef users (n=2,212) in four U.S. cities (Chicago, Houston, Philadelphia and San Francisco). The study examined the effect of three beef cuts (top loin, top sirloin and top round steaks) that varied in USDA Quality Grade (Top Choice, Low Choice, High Select, and Low Select). Consumers were asked to rate each of 12 steaks over a 6-week period for overall like/dislike, juiciness, tenderness, flavor like/dislike and flavor intensity using 23-point hedonic, end-anchored sensory scales. Quality grade influenced consumer sensory responses (Table 2). Consumers rated Top Choice top loin steaks higher for overall like than top loin steaks from lower quality grade classes. Additionally, consumers described Top Choice top loin steaks as juicier and more flavorful then High Select and Low Select top loin steaks. As USDA Quality Grade decreased from Low Choice to High Select and to Low Select, consumers indicated that they did not like the top loin steaks as well, the top loin steaks were drier, tougher, and they decreased in flavor desirability and flavor intensity. USDA Quality Grade influenced the consumer sensory attributes of top sirloin and top round steaks; however, the effect of USDA Quality grade was not as strong for these cuts as previously discussed for top loin steaks. USDA Quality Grade did not account for a high amount of variation in consumer sensory responses. While the relationship between marbling and consumer palatability may be low, it does appear to be consistent Other quality attributes that can be easily measured on a beef carcass on-line that would account for higher amounts of variation in consumer sensory attributes have not been reported. Therefore, marbling or USDA Quality Grade may not be a perfect system and it may not account for a high amount of variation in consumer sensory responses, but it segments beef carcasses into palatability categories more consistently than other proposed quality measures.

The Beef Customer Satisfaction Study was an in-home placement consumer sensory study. An advantage of in-home consumer sensory studies is that information on how beef is handled, prepared, what cooking methods are used and what degree of doneness is preferred can be determined and the effect of these attributes on subsequent consumer sensory perception can be examined. Beef palatability is not only affected by USDA Quality Grade, but Lorenzen et al. (1999), Savell et al. (1999) and Neely et al. (1999) showed that degree of doneness and cooking method played a major role in consumer perceptions of beef palatability. Lorenzen et al. (1999) found that regions of the country (represented by city) cooked top loin steaks to different degrees of doneness and while common cooking methods of grilling, broiling and pan-frying were employed across the four cities, the degree of doneness within a cooking method differed. When the influence of degree of doneness and cooking method on consumer sensory attributes were examined, cooking method and degree of doneness accounted for large segments of the variation in consumer sensory attributes. Cooking method and degree of doneness are personal preferences and can not be controlled. These studies indicate that beef from higher quality grades tended to provide better protection during cooking, so that regardless of cooking method or degree of doneness, steaks with higher amounts of marbling were more acceptable in consumer attributes of juiciness, tenderness, flavor and overall like.

To understand if other quality factors influenced beef consumer acceptability, the top loin steaks were segmented into categories based on Warner-Bratzler shear force (Table 3). Warner-Bratzler shear force categories were defined where top loin steaks with Warner-Bratzler shear force values ≥ 4.55 kg were considered tough as defined by Shackelford et al. (1991) and as used in the two Beef Tenderness Surveys. Top loin steaks with Warner-Bratzler shear force values from 4.54 kg to 3.87 kg were categorized as acceptable; top loin steaks with shear force values from 3.86 kg to 2.74 kg were called tender; and top loin steaks having Warner-Bratzler shear force values less than or equal to 2.73 kg were classified as very tender. As Warner-Bratzler shear force category went from tough to tender, overall like incrementally increased, and consumers rated top loin steaks as juicier, more tender, with higher amounts of flavor and they liked the flavor. This strongly suggests that Warner-Bratzler shear force accounted for variation in consumer's perceptions of eating quality. It is interesting to note that differences in least squares means between the low and high Warner-Bratzler shear force categories were greater than differences in least squares means due to USDA Beef Quality Grade. This suggests that Warner-Bratzler shear force categories segmented consumer sensory responses more than USDA Beef Quality Grades and the addition of a measure that accounts for tenderness differences may provide an additional means of segmenting beef into quality categories to meet consumer preferences.

The trained meat descriptive attribute sensory attributes also were used to define categories (Table 4). While these categories may not be practical (not measurable in real-time on-line in a packing plant), segmenting these data into sensory categories provides understand of if trained sensory meat descriptive attributes correspond to consumer sensory ratings and account for variability in consumer acceptance. Therefore, as new technologies are developed to account for differences in trained sensory attributes, these data can provide insight into if improvements in consumer acceptance would result. As trained sensory panelists rated top loin steaks from dry to juicy, consumer sensory panelists indicated that top loin steaks were more acceptable in overall like, they were juicier, more tender, had higher levels of flavor and they liked the flavor. As trained sensory panelists rated beef top loin steaks from tough to tender, consumers indicated that overall like increased, they rated the top loin steaks as juicier, more tender, more intense in flavor and they increased acceptance of flavor. Increasing trained sensory panel ratings for flavor intensity from bland to intense resulted in increased consumer overall like and flavor ratings. Trained sensory beefy flavor ratings had little affect on consumer sensory responses, except for consumer tenderness ratings. Top loins steaks rated as bland for beefy flavor by trained sensory panelists were tougher according to consumers. As trained sensory beef fat flavor increased from bland to either slightly intense, moderately intense or intense, consumers indicated that top loin steaks were juicier, more tender, and more intense in flavor and they liked the flavor. These data indicate that a minimal level of fat flavor of slightly intense or higher level was important for beef consumer acceptance.

Pork

Quality Traits. At the 1998 Pork Quality and Safety Summit sponsored by the National Pork Producers Council, Meisinger and Miller (1998) discussed pork quality traits. Pork quality traits, as in beef, can be categorized into two areas: 1) visual quality characteristics; and 2) eating quality characteristics, also referred to as meat palatability. Visual pork quality characteristics have been defined as have been defined as water holding capacity or drip loss, lean color, pH (as it relates to drip loss and color), and intramuscular lipid or marbling. Certainly the amount of subcutaneous fat or seam fat, injection site blemishes, and blood splash could be classified as quality characteristics, but for the purpose of this talk, it will be considered that these are obvious defects and that pork that expresses these defects are removed from potential consumer purchase. On the other hand, pork eating characteristics or palatability have been defined as juiciness, tenderness and flavor. It has been generally accepted that the visual quality characteristics are by themselves direct measures of pork quality, but they also have indirect association with eating quality characteristics as previously discussed for beef. For example, pork that is light in color, has high drip loss and a low level of marbling has been associated with decreased juiciness, lower levels of positive pork flavor and increased toughness.

The biggest difference between issues related to the quality attributes of pork than for beef is that water holding capacity or drip loss, color and pH are considered to be more important drives of quality differences. Additionally, in beef, the USDA Beef Quality Grade system provides opportunities to segment beef into quality categories that results in economic differences, a similar system is not in place for pork. As a result, quality variation is not a component of the pork pricing system.

Variability in Quality Traits. Kauffman et al. (1997) conducted the National Pork Quality Project to determine if chlled pork carcasses could be accurately and practically evaluated for quality variation. They sampled 1220 pork carcasses in eight major U.S. pork packing plants over a 5-week period in six States. They classified about 33% of the carcasses in the study as either pale, soft and exudative (PSE) or red, soft and exudative (RSE) and considered these quality classes as Undesirable. Within individual plants, the percentage of PSE plus RSE ranged from 16% to 58% and two plants did not have any PSE. Quality was determined on the loin and loins with drip loss >6%, L* values >50 and ultimate pH <5.6 were classified as PSE. The RSE loins had drip loss >6%, L* values from 43-50 and ultimate pH <5.7. Normal quality loins had drip loss from 3 to 6%, L* values from 43 to 50, and ultimate pH of 5.5 to 5.9. The dark, firm and dry (DFD) loins had drip loss <3%, L* values <43 and ultimate pH values >5.9. The DFD loins were not classified as a quality defect in this study.

These results indicate that variation in U.S. pork quality attributes exist. However, these results do not answer the question of if this variation is important or related to consumer preference. *If the U.S. pork industry reduced the variation in pork quality* *attributes, would customer satisfaction increase domestically and internationally and result in increased demand for U.S. pork?* To begin to answer this question, the results of two consumer sensory studies with U.S. and Japanese consumers will be discussed.

Relationship of Quality Traits to Consumer Acceptance – The United States Consumer. A study was conducted in 1997 by the National Pork Producers Council (NPPC) in cooperation with Texas A&M University, The Ohio State University and Total Research (Chicago, IL) to understand the effect of pork lean quality attributes and consumer acceptability. The study was a central-location consumer sensory study that was conducted in Boston, Chicago and Denver. To participate in the study, consumers had to be pork eaters (1 or more times per week), be greater than 18 years of age, and be willing to travel to the evaluation site. Consumers were seated separate from the sample preparation area and up to 10 consumers participated in one session and six to eight sessions were conducted per day for two days within each city. Each consumer evaluated 12 samples where 4 samples were pork loin chops, 4 samples were fresh pork inside ham chops, and 4 samples were chicken breast. Consumers were served 2 samples per presentation and received at total of six presentation. Within a presentation, consumers were served either a loin chop and inside ham chop, a loin chop and a chicken breast, or a inside ham chop and a chicken breast. The loin and ham chops were from the same animal and the chicken breasts were commercially purchased in each respective city to be representative of chicken breast commercially available within the markets were the study was being conducted. The pork used for this study were from NPPC's Quality Lean Growth Modeling Project (QLGM) (Miller, 1997). In this project, the pork was selected from hogs from six genetic types (are Berkshire, Duroc, Danbred, Newsham Hybrid, Hampshire, and DeKalb genetics) fed one of four diets that varied in dietary lysine content and slaughtered at one of three slaughter weights (270, 300 or 330). This experimental design created variation in muscle pH, intramuscular fat, lean color, lean firmness and meat tenderness and was an excellent source of pork to examine the effect of quality attributes on consumer acceptance.

Within a city, the pork carcasses that were slaughtered the two preceding weeks from the QLGM project were evaluated for ultimate pH (taken in the longissimus muscle at the last rib 24 hours postmortem), ether extractable lipid in the longissimus muscle at the last rib, and Warner-Bratzler shear force (kg) from a 10th rib loin chop. Within a week, the pork carcasses were segmented into three categories within a quality trait so that category 1 represented the loins with the lowest pH, the lowest lipid percentage and the highest Warner-Bratzler shear force values. Categories 2 and 3 were incrementally higher for pH and lipid and incrementally lower for Warner-Bratzler shear force values. These categories were used to assign pork samples within a consumer so that a consumer received samples that varied in pH, lipid content and Warner-Bratzler shear force. The same quality attributes were measured on the inside ham to understand the effect of pH, lipid content and tenderness to consumer acceptance in the fresh inside ham chop.

The loin chops, inside ham chops and chicken breasts were individually cooked to an internal temperature of 70°C in convection ovens. Each cut was cut into 1.25 cm cubes and consumers received two samples per cut. Consumers evaluated each sample for juiciness like/dislike, tenderness like/dislike, flavor like/dislike and overall like/dislike using 5-point, end-anchored hedonic scales where 1= dislike extremely and 5=like extremely.

City, cut and the interaction of cut by city (Table 5) affected pork consumer sensory responses. In general, consumers in Boston rated cuts lower in juiciness like, tenderness like, flavor like and overall like than consumers in Denver and Chicago. However, depending on the cut, consumers within a city responded differently in consumer sensory attributes. Overall, consumers liked the juiciness, the tenderness, the flavor and the overall acceptance of chicken breasts when compared to either loin or inside ham chops. Additionally, pork consumers rated loin and ham chops similarly for like of the juiciness and flavor, but they liked the tenderness and overall acceptability of the loin chops compared to the inside ham chops. Consumer rated cuts differently within a city. In Denver, consumers rated the chicken breast highest for acceptance of tenderness, flavor and overall like, but indicated that the juiciness of chicken and loin chops were similar and that they did not like the juiciness of inside ham chops. Additionally, they rated the inside ham chop lower for tenderness like and overall like when compared to loin chops. However, consumers in Chicago similarly rated the chicken breast with the highest like rating for the four sensory attributes, but they liked the inside ham chop when compared to the loin chop for tenderness, flavor and overall acceptance. Consumers in Boston consistently rated chicken breasts higher than loin chops and loin chops as higher in acceptance than ham chops for consumer sensory attributes.

So differences in consumer sensory attributes were reported and geographic location influences the perception of acceptability. *What does this mean for differences in quality attributes? Did quality attributes influence consumer sensory responses?* As pork quality attributes varied due to the experimental design, the categories used to segment the pork within a week were used to understand if differences in pH, lipid content and Warner-Bratzler shear force affected consumer sensory responses for loin chops (Table 6) and the fresh inside ham chops (Table 7). For loin chops, consumer sensory responses differed by pH category and shear category, but consumer sensory responses did not differ as intramuscular lipid percentage increased. Consumer liked the juiciness, the tenderness of loin chops from the high pH category more than loin chops from either pH categories 1 or 2. Additionally, they preferred loin chops from pH category 3 over loin chops from pH categories 1 and 2. As Warner-Bratzler shear force values decreased, consumers indicated that they liked the juiciness, the tenderness, the flavor, and the overall acceptability of loin chops. However, loin chops from shear categories 1 and 2 did not differ in consumer juiciness like and loin chops from shear categories 2 and 3 did not differ in consumer flavor and overall acceptance.

These results indicate that pH and shear force affected consumer perceptions of palatability and could be used as quality attributes to segment pork into more homogeneous quality categories or grades. It is important to note that the pH, lipid and shear categories were defined within a day of slaughter. As pH and Warner-Bratzler shear force values can be highly affected by slaughter day and plant, it is important that classification for these attributes occur within a plant and slaughter day.

For the consumer study, the pH, lipid and Warner-Bratzler shear force values from the loin were used to segment or randomly assign loin and ham chops from the same animal to a consumer. However, to understand the effect of the pH, lipid and Warner-Bratzler shear force on consumer acceptability of inside ham chops, the pH, lipid percentage, and Warner-Bratzler shear force categories within a slaughter week for the inside ham chops were examined (Table 7). As reported for loin chops, as pH increased, consumers liked the juiciness, the tenderness, the flavor and the overall acceptability of inside ham cuts. Consumer sensory responses were not affected by lipid category and as Warner-Bratzler shear force decreased, consumers liked the tenderness of inside ham chops, but other consumer sensory attributes were not affected.

Relationship of Quality Traits to Consumer Acceptance – The Japanese Consumer. The previous data addressed the relationship between pork quality attributes and U.S. consumers acceptance, to understand these relationships with Japanese consumers, a cooperative study was conducted between NPPC, the U.S. Meat Export Federation, Texas A&M University, Colorado State University, The Ohio State University, the University of Illinois, Iowa State University and Total Research (Miller et al. 1999). The objective of this research was to conduct a consumer sensory evaluation study in Tokyo to determine the relationship between U.S. pork quality attributes and Japanese consumer preference for visual appearance and eating quality of pork. Note that this study incorporated the visual and eating quality consumer attributes.

To assure that pork loins varied in quality, producers with Berkshire, Duroc, and Landrace breed types, where history of quality attributes were known, were identified. Pork from these lines have been shown to produce dark colored meat with a high amount of marbling (Berkshire), normal to dark colored meat with high amount of marbling (Duroc) and pale meat with low amount of marbling (Landrace). These breed types were selected to provide the variability in pH, color and marbling to represent the practical extremes for U.S. pork. Thirty five hogs per breed type were slaughtered at Quality Pork Processors in Austin, MN on each of two slaughter days and pork loins (n=196) were selected. From the blade-end, ham-end and loin eye at the 10th rib, pH, NPPC and Japanese subjective color, NPPC firmness score, marbling score, reflectance, CIE L*, CIE a* and CIE b* values using two different Minolta colorimeters and a HunterLab Miniscan CIE spectrophotometer readings were obtained. For the Minolta and HunterLab Miniscan CIE evaluations, three readings were obtained per lean cut surface using a small aperture setting and one reading per lean surface was recorded per lean cut surface using the large aperture (50mm) setting. A RBG camera also was used to evaluate color of the three lean surfaces. Loins were fabricated so that samples could be collected for lipid percentage (by ether extraction), and Warner-Bratzler shear force, Instron star-probe shear force, and trained meat descriptive attributes sensory analysis. The whole loin from the other side of the carcass was identified and packaged for air transport to Japan. The pH, NPPC and Japanese subjective color score, Instron star-probe tenderness measurement, and marbling score were used to classify loins into quality categories for the consumer sensory study. Categories were defined as follows: pH: 1= low, 2 = middle; and 3 = high; lipid: 1 = low; 2 = middle; and 3 = high; Instron star-probe: 1 = toughest; 2 = middle; and 3 = most tender; Japanese color score: 1 = lightest and 6 = darkest. Japanese consumers (n=84) participated in a central-location sensory study on May 21, 1998 in Tokyo, Japan. Consumers were selected to range in age, income, to be pork eaters and to have approximately equal distribution of both sexes.

Loins were cut in Japan immediately prior to consumer evaluation into pork chops (2.54 cm thick) for consumer palatability evaluation. Additionally, two chops sliced to approximately 10 mm in thickness were obtained immediately adjacent to where the consumer sensory chop was removed for color evaluations. Pork chops for palatability determinations were cooked to 70°C in convection ovens. Chops were cut into 1.25 cm cubes and consumers received two samples per chop. Consumers were presented with samples from two chops at each serving. The two samples within a serving differed in pH, marbling score, Instron star-probe tenderness values, and/or Japanese color score. This enabled evaluation of eating quality difference between different quality classes of loin chops within a consumer. Consumers were presented a total of twelve samples. Japanese consumers evaluated each sample for overall like/dislike, flavor, tenderness, and juiciness as in the U.S. protocol using 5-point hedonic, end-anchored category scales.

For Japanese visual quality assessment, 2-10 mm pork loin slices from a loin were placed in 7.6 x 20 cm Styrofoam® display trays and PVC over-wrapped. Packaged pork loin slices presented to each consumer were derived from the same loin as samples evaluated during sensory evaluation. Consumers were asked to evaluate twelve samples for overall appearance like/dislike, marbling level, color intensity, and color desirability using 5-point, end-anchored hedonic or intensity category scales. All samples were identified with random three-digit codes and consumers did not know that they were evaluating U.S. pork.

Lean quality and color characteristics for the pork loins at 24 hours postmortem obtained from the blade-end, 10th rib loin longissimus muscle and the ham-end of the loin were variable and represented expected variation of pork loins in the U.S. (Table 8; 10th rib characteristics only). Additionally, pork loins varied in lipid, shear force and trained meat descriptive sensory attributes (Table 9). On average, pork chops were moderately juicy and tender, had very little chewiness (also an indication of connective tissue), were low in flavor intensity, and had a low amount of off-flavors. However, standard deviations and the range of values for mechanical tenderness and sensory attributes showed substantial variation and ranges in these attributes, indicating that pork loins were variable in sensory attributes and would provide adequate variation to test Japanese consumer preferences for eating quality.

To understand what Japanese consumer sensory attributes were most highly related to overall like/dislike for eating quality and overall visual like/dislike, partial regression correlation coefficients between consumer attributes are calculated. Japanese consumer overall taste acceptability was most highly related to pork flavor (r=.86). However, juiciness, tenderness and aroma (r=.73, .71 and .60, respectively) also were related to Japanese consumer overall taste acceptability. Not surprising, overall taste acceptability was not highly related to overall visual acceptability. As consumers were not provided visual raw samples at the time of taste evaluation, this relationship would be expectantly low. This does not mean that when consumers purchase a pork sample from the retail store and prepare it at home, that these factors do not influence their taste perception. This study was not designed to answer the question of the interaction between visual acceptability and taste perception, in fact, the study was designed to remove this relationship so that we could better understand meat quality characteristics that relate to consumer taste and visual acceptance. The fact that overall taste acceptability and overall visual acceptability were not related indicated that the taste and visual evaluations were independent.

Appearance of the pork in the package and color like/dislike were highly related to Japanese visual overall acceptability (r=.80 and .75, respectively). Therefore, a Japanese consumers' first impression of their like or dislike of the overall appearance and the color of pork drive their overall decision on like or dislike of the visual acceptability. The amount of fat as rated by consumers was related to their overall visual acceptability, but the amount of fat that consumers perceived did not influence visual acceptability as strongly as appearance and color. Interestingly, color intensity was only moderately related to consumer visual acceptability indicating that even though Japanese consumers rated the pork samples from light to dark (or they differentiated color variation in our samples as will be discussed below), they did not discriminate heavily based on color intensity. In other words, Japanese consumers do not have a preference for darker colored pork as generally perceived, but that they select against lighter colored pork.

Traditionally, pork loins are selected in U.S. plants based on lean color, usually in the loin muscle at the last or 10th rib, or in either the blade-end or ham-end face. Color is almost always based on selection using the Japanese color standards. To understand if Japanese color scores in either of the three lean surfaces were related to Japanese consumer acceptance, the effect of Japanese color score on Japanese consumer palatability and visual acceptance was examined (Table 10; only data from the blade-end and the 10th rib are presented). Pork with a Japanese color score of 1 in the blade-end was rated lower in juiciness and overall taste than pork chops with a Japanese color scores of 2 or greater. Japanese consumers did not like the color or overall appearance of pork chops from loins with Japanese color score of 1 in the blade-end when compared to pork chops from loins with Japanese color scores of 2 or higher. For pork loins that had a Japanese color score of 1 in the blade-end, Japanese consumers rated these chops as lighter in color and indicated that they did not like the color or overall appearance. For pork chops from pork loins with a Japanese color score of 2 in the blade-end, consumers rated the color intensity as darker than chops from level 1 loins and they indicated that they liked the color and the overall visual appearance more than Japanese color score 1 chops. However, for pork having a Japanese color score of 3 or higher in the blade-end, Japanese consumers did not differ in preference for color or overall visual acceptability. When Japanese color scores were evaluated on the lean at the 10th rib, consumer juiciness was not affected. However, Japanese consumers indicated that chops from loins with Japanese color scores of 1 or 2 in the 10th rib were tougher than chops from loins with Japanese color scores of 2 or higher. Pork chops from loins with a 1 Japanese color rating in the 10th rib lean were rated lighter than chops from loins with a 2 or 3 rating and loin chops rated a 4, 5 or 6 in the 10th rib lean were rated darker. However, they liked the color and overall acceptability of pork chops where the 10th rib lean was rated as 3, 4, 5 or 6 for Japanese color score. Japanese color scores from the ham-end did not segment pork chops into categories that influenced consumer preference for eating acceptability and only slight differences for overall visual acceptability (data not presented). For selecting loins in the U.S. for the Japanese market, these data suggest that evaluating lean color in the 10th rib and selecting loins with Japanese color scores of 3, 4, 5 or 6 would meet Japanese consumer preference. As breaking loins at the 10th rib may not be acceptable, selecting loins having Japanese color scores of 3 or higher in the blade-end would meet Japanese consumer preferences.

When NPPC color scores were used to segment pork loins into color quality classes, there were differences for juicy preferences across NPPC color classes (Table 11). In general, pork chops from loins rated as an NPPC color score of 1, regardless of whether the score was for blade-end or the 10th rib lean, the pork chops were drier. Japanese consumer rated color intensity incrementally with NPPC color score from the 10th rib. However, consumers liked the color and the overall acceptability of pork chops from 2, 3, 4 or 5 NPPC color scores categories. This strongly supports the hypothesis that Japanese consumers do not necessarily like darker meat, but that they do not like light colored pork.

Higher marbling score has been implicated as being related to higher consumer eating and visual preference. The NPPC recently revised their marbling categories. These new categories are based on visual assessment of intramuscular fat, but they are anchored with chemical lipid percentages. Therefore, the chemical lipid of pork chops was used to estimate the new NPPC marbling score. The ability of the new NPPC marbling score to segment pork chops into categories related to consumer acceptability is presented (Table 12). Japanese consumers tended to rate pork chops with higher NPPC marbling scores as juicier, more flavorful and higher in overall taste like than lower marbling levels. For visual consumer attributes, Japanese consumers tended to increase their acceptability for appearance, color and amount of fat for pork chops from low new NPPC marbling scores up to new NPPC marbling score of 5. Japanese consumers had lower like for the appearance, color and amount of fat in pork chops from new NPPC marbling score of 6 when compared to these same attributes for new NPPC marbling score of 5. Either category 6 pork chops had too much marbling that Japanese consumers did not prefer or the low frequency of samples in the 6 category affected this relationship.

The effect of NPPC firmness score on Japanese consumer palatability and visual acceptability is reported in Table 13. Pork chops from loins with NPPC firmness 5 scores in the 10th rib lean were rated as juicier and as more tender by Japanese consumers. Additionally, pork chops with ham-end lean NPPC firmness scores of 5 tended to be more tender. Firmness score influenced visual Japanese consumer acceptability more than palatability ratings. Japanese consumers rated pork chops as lighter in color and less acceptable overall when chops were from loins with 1 NPPC firmness scores in the blade-end. For pork loins with NPPC firmness scores of 1, 2 or 3 in the 10th rib lean, Japanese consumers rated the pork chops slightly lower in overall acceptability and appearance. For NPPC firmness scores from the 10th rib lean, Japanese consumers rated pork chops with NPPC firmness scores of 1 or 2 as lighter in color than pork chops with NPPC firmness scores of 3 and they rated pork chops with NPPC firmness scores of 4 or 5 as darkest. When NPPC firmness scores were defined in the ham-face lean, Japanese consumers indicated that pork chops from NPPC firmness score of 1 was lighter than other pork chops and that overall visual acceptability was lower for firmness levels 1 and 2. This is not surprising as firmness scores often coincide with color where softer pork also can be lighter. As we did not have red, soft and exudative lean in these pork loins, these firmness/color relationships where light pork also was soft, was expected.

To verify that categories used to segment pork loins induced variation in Japanese consumer acceptability and to understand how these categories influenced Japanese consumer acceptability, least squares means from Japanese consumer categories were evaluated (Table 14). Japanese color score, the fourth variable used to categorize pork loins for variation, was previously presented. As pH increased, Japanese consumers rated pork chops as more acceptable for juiciness, tenderness, overall taste and color intensity. Therefore, pH can be used to select pork loins for improved Japanese consumer acceptability. As Instron star-probe shear values decreased (pork chops became more tender), Japanese consumers rated pork chops as more desirable for juiciness, tenderness, flavor, overall taste and color intensity. As lipid percentage increased, Japanese consumers rated pork chops as slightly lower in tenderness like, but they rated higher lipid pork chops as more acceptable for appearance, color, amount of fat and overall appearance.

Conclusions

Beef. Variation in U.S. beef exists, but the majority of U.S. beef is classified as USDA Choice and Select quality grades. The U.S. beef industry has seen a reduction in number of USDA Standard carcasses. Simultaneously, the Warner-Bratzler shear force values of randomly selected cuts from the retail beef segment decreased from 1990 to 1998. Therefore, it can be concluded that the USDA Beef Quality Grading system is doing an adequate job. However, a percentage of beef cuts are being merchandized prior to receiving adequate aging, less than 7 to 10 days, and improvement of tenderness of round cuts is needed.

The strength of the USDA Beef Quality Grade system is further supported by beef consumer data. The Beef Customer Satisfaction Study showed that while the USDA Beef Quality Grading system was not prefect, it adequately segmented beef into quality categories that were reflective of consumer acceptance. The system is obviously not perfect and still only accounts for a small segment of the variation in consumer acceptance. Other quality characteristics, if they were measurable on a beef carcass or in cuts in the packing plant, could provide additional information on beef eating quality, especially methods that would account for more of the variation in beef tenderness. Juiciness and flavor are important to beef consumers and these attributes should not be forgotten. The factors in the USDA Beef Quality Grading system most likely continue to work as they help to account for variation in consumer's perception of all three components of beef palatability, juiciness, tenderness and flavor.

The challenge of the beef industry is in producing a higher percentage of USDA Choice (increasing the percentage of beef with small, modest and moderate marbling). An understanding of the use of genetic markers for marbling and tenderness in combination with production practices that enable expression of this genetic potential are needed.

Pork. It is obvious that variation in pork quality attributes exist and that some quality attributes affect consumer acceptance and perception of meat palatability. Quality assessment needs to be included in the pork pricing or value system.

First, what pork quality attributes need to be used? Of the quality attributes measured in U.S. Pork Consumer Study, pH more closely segmented pork lion and inside ham chops into categories than either lipid or Warner-Bratzler shear force. One of the study weaknesses was that the effect of pork visual color and firmness characteristics were not included. While pH has a relationship with color and lean firmness and therefore, also may assist in accounting for consumer acceptance of these visual attributes, it is beyond the scope of these data to test the combined effect. However in the Japanese consumer study, pH categories segmented consumer responses for visual and eating acceptability and most likely the same relationship would be reported for U.S. consumers. This issue needs to be addressed with U.S. consumers. As pH is indirectly related to multiple pork quality attributes, it most likely showed the greatest ability to segment pork based on consumer visual and eating quality attributes compared to other quality measures. Additionally, the combined effect of a color measurement, either instrumental or a human score, marbling, firmness, or tenderness (these quality attributes did not have as strong of an effect, but accounted for some differences in consumer acceptability) may improve the segmentation of pork loins into quality classes for U.S. and Japanese consumers. However, these issues have not been addressed. Research that incorporates the combined effect of visual appearance and eating quality is needed to ascertain if pH, color, firmness, tenderness, marbling or any combination of these attributes that need to be used to segment pork into quality classes.

Now that we have indication of what pork quality attributes to measure, how do we get a reduction in the variation in pork quality attributes? The reduction of variability in pork quality characteristics is not going to occur unless a measurement of pork quality is included in the pricing matrix for pork. Pork producers may agree that pork quality is important, but many of them do not know the quality of the pork that they produce. Additionally, even if they knew the quality of the pork that they produce, there is no economic incentive to reduce the variation in pork quality. Automated grading or quality assessment systems to provide the tools needed to assess quality in the packing plant should be a high priority for the pork industry. Systems that would provide consistent, reliable values to differentiate pork quality that then could be incorporated into a pork pricing system and that also would provide an avenue for feedback to the producers is needed before the pork industry can make great strides in reducing variability in pork quality and increasing subsequent pork demand.

Genetic evaluation programs need to assess pork quality attributes to provide the basis for genetic selection for pork quality in combination with increased leanness. Without genetic selection, even if a pricing system was put into place, producers need the genetic tools to improve pork quality. Elimination of the Halothane gene and further assessment of the RN gene effect on pork quality are need. A further understanding of the interactions of genetics, nutrition and environment are needed to provide producers with the mechanisms to fully capitalize the economic potential of a pricing system that included quality and leanness measures.

References

Boleman, S.L., S.J. Boleman, W.W. Morgan, D.S. Hale, D.B. Griffin, J.W. Savell, R.P. Ames, M.T. Smith, J.D. Tatum, T.G. Field, G.C. Smith, B.A. Bardner, J.B. Morgan, S.L. Northcutt,, H.G. Dolezal, D.R. Gill and F.K. Ray. 1998. National Beef Quality Audit-1995: Survey of producer-related defects and carcass quality and quantity attributes. J. Anim. Sci. 76:96-103.

Brooks, J.C., J.B. Belew, D.B. Griffin, B.L. Gwartney, D.S. Hale, W.R. Henning, D.D. Johnson, J.B. Morgan, F.C. Parrish, Jr., J.O. Reagan and J.W. Savell. 2000. National Beef Tenderness Survey – 1998. J. Anim. Sci. (Accepted).

Kauffman, R.G., and Animal Science 405 (Livestock and Meat Distribution Class(. 1997. National pork quality project. Proc. Of Pork Quality Summit, National Pork Producers Council, Des Moines, IA.

Lorenzen, C.L., D.S. Hale, D.B. Griffin, J.W. Savell, K.E. Belk, T.L. Frederick, M.F. Miller, T.H. Montgomery and G.C. Smith. 1993. National Beef Quality Audit: Survey of producer-related defects and carcass quality and quantity attributes. J. Anim. Sci. 71:1495-1502.

Lorenzen, C.L., T.R. Neely, R.K. Miller, J.D. Tatum, J.W. Wise, J.F. Taylor, M.J. Buyck, J.O. Reagan and J.W. Savell. 1999. Beef Customer Satisfaction: Cooking method and degree of doneness effects on the top loin steak. J. Anim. Sci. 77"637-644.

Meisinger, D.J. and R.K. Miller. 1998. Pork Quality Issues. In: Pork Quality and Safety Summit. p. 29-32. National Pork Producers Council, Des Moines, IA.

Miller, R.K. 1997. Lean Growth Modeling Study: Ham quality update. In: Proceedings of the Meat Industry Reserarch Conf. October. American Meat Institute, Washington, DC.

Miller, R.K., K. Grones, C. Cloud, M. Vonada, K. Belk, S. Moeller, F. McKeith, C. Fedler, K. Prusa, A. Curriquairy, D. Meisinger, R. Goodwin, J. Cravens, W.R. Lloyd and J. Morton. 1999. Japanese Perception of Pork Quality. Final Report to Illinois Soybean Program Operating Board. U.S. Meat Export Federation, National Pork Producers Council and Texas A&M University, Denver, CO, Des Moines, IA and College Station, TX.

Neely, T.R., C.L. Lorenzen, R.K. Miller, J.D. Tatum, J.W. Wise, J.F. Taylor, M.J. Buyck, J.O. Reagan and J.W. Savell. 1999. Beef Customer Satisfaction: Cooking method and degree of doneness effects on the top round steaks. J. Anim. Sci. 77:653-660.

Neely, T.R., C.L. Lorenzen, R.K. Miller, J.D. Tatum, J.W. Wise, J.F. Taylor, M.J. Buyck, J.O. Reagan and J.W. Savell. 1998. Beef Customer Satisfaction: Role of cut, USDA Quality Grade, and city on in-home consumer ratings. J. Anim. Sci. 76:1027-1032.

Savell, J.W. and H.R. Cross. 1988. The role of fat in the palatability of beef, pork, and lamb. In: Designing Foods: Animal Product Options in the Market Place. p. 345-356. National Academy Press, Washington, DC.

Savell, J.W., C.L. Lorenzen, T.R. Neely, R.K. Miller, J.D. Tatum, J.W. Wise, J.F. Taylor, M.J. Buyck and J.O. Reagan. 1999. Beef Customer Satisfaction: Cooking method and degree of doneness effects on the top sirloin steak. J. Anim. Sci. 77:645-652.

Shackelford, S.D., J.B. Morgan, J.W. Savell and H.R. Cross. 1991. Identification of threshold levels for Warner-Bratzler shear force in beef top loin steaks. J. Muscle Foods .

USDA. 1989. Official United States standards for grades of carcass beef. USDA Agricultural Marketing Service, Washington, DC.

Table 1. Warner-Bratzler shear force values (WBS) for the National Beef Tenderness Survey (NBTS) from 1990[a] and the National Beef Tenderness Survey from 1998[b] for rib and loin retail cuts.

	NBTS 1990		NBTS 1998	
Steak	n	WBS, kg	n	WBS, kg
Ribeye	98	3.4	200	2.8
Porterhouse	*	*	56	2.6
T-bone	*	*	147	2.7
Top loin	123	3.3	269	2.7
Top sirloin	85	3.6	118	2.9
Clod	34	4.0	68	3.0
Chuck roll	39	4.2	135	3.3
Top round	67	5.2	91	3.6
Eye of round	39	4.7	177	4.1
Bottom round	46	4.4	97	5.0

[a]From Morgan et al. (1991).
[b]From Brooks et al. (2000).

Table 2. Least squares means for U.S. Beef Customer Satisfaction consumer sensory attributes[a] as effected by city and quality grade.

USDA Quality Grade	Overall Like/Dislike	Juiciness	Tenderness Like/Dislike	Flavor Intensity	Flavor Like/Dislike
Top Loin Steaks[b]					
Top Choice	19.3^{e}	18.6^{e}	19.0*	19.4^{e}	19.1*
Low Choice	19.0^{f}	18.3^{f}	19.1	19.2^{e}	19.2
High Select	18.9^{fg}	18.2^{f}	18.8	19.1^{f}	18.9
Low Select	18.7^{g}	17.9^{g}	18.6	18.9^{g}	18.8
Top Sirloin Steaks[c]					
Top Choice	17.9	17.5†	17.9^{e}	18.4†	18.4†
Low Choice	18.2	17.7	17.8^{e}	18.5	18.5
High Select	17.9	17.3	17.6^{f}	18.3	18.3
Low Select	17.8	17.3	17.7^{ef}	18.3	18.3
Top Round Steaks[d]					
Top Choice	17.1	16.3†	16.7†	17.5†	17.6†
Low Choice	17.0	16.0	16.5	17.5	17.5
High Select	16.9	16.1	16.5	17.4	17.5
Low Select	16.9	15.8	16.4	17.3	17.3

[a] Consumers attributes were rated as 1=dislike extremely, not at all juicy, not at all tender, dislike extremely, and no flavor at all, respectively and 23=like extremely, extremely tender, extremely juicy, like extremely, and an extreme amount of flavor, respectively.

[b] Values from Lorenzen et al. (1999).

[c] Values from Savell et al. (1999)

[d] Values from Neely et al. (1999).

[efg] Least squares means within a column and a cut lacking a common superscript differ ($P < .05$).

* Means were calculated from the interaction between quality grade and cooking method (Lorenzen et al., 1999) and mean separations were not presented.

† Means were calculated from the interaction between degree of doneness and USDA Quality Grade as presented by Savell et al. (1999) for top sirloin steaks and Neely et al. (1999) for top round steaks, respectively, and mean separations were not presented.

Table 3. Consumer sensory attributes[a] for top loin steaks as effected by Warner-Bratzler shear force categories from the U.S. Beef Customer Satisfaction Study.

Warner-Bratzler shear force category[b]	n	Overall Like/Dislike	Juiciness	Tenderness	Flavor Intensity	Flavor Like/Dislike
P-value[c]		.0001	.0001	.0001	.0001	.0001
Tough	15	17.7^{d}	17.0^{d}	17.1^{d}	17.8^{d}	18.0^{d}
Acceptable	36	18.5^{e}	17.9^{e}	18.0^{e}	18.8^{e}	18.9^{e}
Tender	262	18.9^{f}	18.2^{e}	18.8^{f}	18.9^{e}	19.1^{e}
Very Tender	295	19.2^{g}	18.5^{f}	19.2^{g}	19.2^{f}	19.3^{f}
RSD		2.50	2.66	2.58	2.39	2.40

[a] Consumers attributes were rated as 1=dislike extremely, not at all juicy, not at all tender, dislike extremely, and no flavor at all, respectively and 23=like extremely, extremely tender, extremely juicy, like extremely, and an extreme amount of flavor, respectively.

[b] Warner-Bratzler shear force categories were defined as Tough = shear force values ≥ 4.55; Acceptable = shear force values 3.87 to 4.54 kg; Tender = shear force values 2.74 to 3.86 kg; and Very Tender = shear force values ≤ 2.73 kg.

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

[defg] Least squares means within a column lacking a common superscript differ ($P < .05$).

Table 4. Least squares means for consumer sensory responses[a] for top loin steaks as effected by trained meat descriptive attribute sensory categories

Trained Sensory category	n	Overall Like/Dislike	Juiciness	Tenderness	Flavor Intensity	Flavor Like/Dislike
Juiciness[b]		.0001	.0001	.0001	.01	.0002
Dry	6	18.8^{gh}	18.2^{gh}	18.9^{hi}	18.8^{gh}	18.8^{g}
Slightly juicy	342	19.0^{h}	18.3^{h}	18.8^{h}	19.0^{gh}	19.4^{h}
Juicy	172	19.3^{h}	18.6^{h}	19.2^{i}	19.2^{h}	18.9^{h}
RSD		2.51	2.67	2.60	2.41	2.41
Overall Tenderness[c]		.0001	.0001	.0001	.0003	.0 001
Tough	6	17.2^{g}	16.6^{g}	16.8^{g}	17.9^{g}	17.9^{g}
Slightly tender	69	18.6^{h}	17.8^{h}	18.2^{h}	18.7^{g}	18.8^{h}
Moderately Tender	388	19.0^{i}	18.3^{i}	18.9^{i}	19.0^{h}	19.1^{i}
Tender	145	19.3^{j}	18.6^{j}	19.3^{j}	19.2^{i}	19.4^{j}
RSD		2.51	2.67	2.59	2.40	2.41
Flavor Intensity[d]		.05	.27	.10	.0058	.0123
Bland	65	18.8^{g}	18.0	18.6	18.7^{g}	18.8^{g}
Slightly intense	272	19.1^{gh}	18.3	18.9	19.1^{i}	19.2^{h}
Moderately intense	153	18.8^{g}	18.2	18.9	18.8^{gh}	19.0^{g}
Intense	118	19.2^{h}	18.4	19.0	19.1^{hi}	19.2^{h}
RSD		2.52	2.69	2.62	2.40	2.41
Beefy Flavor[e]		.44	.30	.02	.20	.17
Bland	81	1819.8	18.1	18.5^{g}	18.8	18.9
Slightly intense	250	19.0	18.3	18.8^{h}	19.0	19.1
Moderately intense	212	19.1	18.4	19.0^{h}	19.1	19.2
Intense	65	19.1	18.3	19.1^{h}	19.0	19.2
RSD		2.52	2.69	2.61	2.41	2.41
Beef Fat Flavor[f]		.06	.007	.0051	.0134	.0387
Bland	52	18.6	17.7^{g}	18.4^{g}	18.6^{g}	18.7^{g}
Slightly intense	267	19.0	18.2^{h}	18.8^{h}	19.0^{h}	19.1^{h}
Moderately intense	255	19.0	18.4^{h}	19.0^{h}	19.0^{h}	19.2^{h}
Intense	34	19.2	18.7^{h}	19.1^{h}	19.3^{h}	19.3^{h}
RSD		2.52	2.68	2.61	2.40	2.41

[a] Consumers attributes were rated as 1=dislike extremely, not at all juicy, not at all tender, dislike extremely, and no flavor at all, respectively and 23=like extremely, extremely tender, extremely juicy, like extremely, and an extreme amount of flavor, respectively.
[b] Juiciness categories: Dry = trained sensory scores ≤ 3.99; Slightly dry = trained sensory scores of 4.00 to 4.99; Slightly juicy = trained sensory scores of 5.00 to 5.99; Juicy = trained sensory scores of ≥ 6.00.
[c] Overall tenderness categories: Tough = trained sensory scores ≤ 4.99; Slightly tender = trained sensory scores of 5.00 to 5.99; Moderately tender = trained sensory scores of 6.00 to 6.99; Tender = trained sensory scores of ≥ 7.00.
[d] Flavor Intensity categories: Bland = trained sensory scores ≤ 5.24; Slightly intense = trained sensory scores of 5.25 to 5.74; Moderately intesne = trained sensory scores of 5.74 to 5.99; Intense = trained sensory scores of ≥ 6.00.
[e] Beef Flavor categories: Bland = trained sensory scores ≤ 2.99; Slightly intense = trained sensory scores of 3.00 to 3.49; Moderately intesne = trained sensory scores of 3.50 to 3.99; Intense = trained sensory scores of ≥ 4.00.
[f] Beef Fat Flavor categories: Bland = trained sensory scores ≤ 1.49; Slightly intense = trained sensory scores of 1.50 to 1.99; Moderately intesne = trained sensory scores of 2.00 to 2.49; Intense = trained sensory scores of ≥ 2.50.
[ghij] Least squares means within a column lacking a common superscript differ (P < .05).

Table 5. Least squares means for consumer sensory traits[a] as effected by city and cut for the U.S. Pork Consumer Study.

Trait	Juiciness	Tenderness	Flavor	Overall Like
n	5383	5381	5380	5374
City	.0001[b]	.0002	.0001	.0006
Denver	3.5^{d}	3.6^{d}	3.4^{d}	3.4^{d}
Chicago	3.5^{d}	3.5^{d}	3.4^{d}	3.4^{d}
Boston	3.3^{c}	3.4^{c}	3.3^{c}	3.3^{c}
Cut	.0001	.0001	.0001	.0001
Chicken	3.6^{d}	4.1^{e}	3.6^{d}	3.7^{e}
Loin chop	3.3^{c}	3.3^{d}	3.3^{c}	3.2^{d}
Inside ham chop	3.3^{c}	3.2^{c}	3.2^{c}	3.2^{c}
City x Cut	.0001	.0001	.0001	.0001
Denver x Chicken	3.5^{e}	4.0^{f}	3.6^{f}	3.6^{f}
Denver x Loin chop	3.6^{f}	3.5^{e}	3.4^{e}	3.4^{e}
Denver x Inside ham chop	3.4^{d}	3.2^{d}	3.3^{de}	3.2^{d}
Chicago x Chicken	3.9^{g}	4.3^{g}	3.7^{h}	3.9^{g}
Chicago x Loin chop	3.2^{c}	3.1^{c}	3.1^{c}	3.0^{c}
Chicago x Inside ham chop	3.4^{de}	3.2^{d}	3.3^{d}	3.2^{d}
Boston x Chicken	3.5^{ef}	3.9^{f}	3.5^{g}	3.6^{f}
Boston x Loin chop	3.2^{cd}	3.3^{d}	3.3^{d}	3.2^{d}
Boston x Inside ham chop	3.2^{c}	3.0^{c}	3.1^{c}	3.0^{c}
RSD[i]	1.12	1.10	1.05	1.05

[a] Consumer attributes were evaluated using a 5-point hedonic, end-anchored sensory scale where 1=dislike extremely and 5=like extremely.
[b] P-value from the Analysis of Variance table.
[cdefgh] Least squares means within a column and a trait lacking a common superscript differ (P < .05).
[i] RSD=Residual Standard Deviation from the Analysis of Variance table.

Table 6. Least squares means for consumer sensory traits[a] as effected by predetermined categories of lipid, Warner-Bratzer shear force, and pH from loin chops from the U.S. Pork Consumer Sensory Study.

Trait	n	Juiciness	Tenderness	Flavor	Overall Like
pH Category		.04	.0165	.06	.03
1 Low	648	3.3[d]	3.3[d]	3.2	3.2[d]
2 Medium	620	3.3[d]	3.3[d]	3.2	3.2[d]
3 High	498	3.5[e]	3.4[e]	3.4	3.4[e]
RSD[c]		1.13	1.08	1.10	1.03
Lipid Category		.20	.19	.09	.18
1 Low	427	3.4	3.3	3.3	3.2
2 Medium	857	3.3	3.3	3.2	3.2
3 High	482	3.4	3.4	3.4	3.3
RSD[c]		1.3	1.08	1.05	1.03
Shear Category		.0004	.0001	.0004	.0001
1 High	379	3.2[d]	3.1[d]	3.1[d]	3.0[d]
2 Medium	844	3.4[d]	3.3[e]	3.3[e]	3.3[e]
3 Low	520	3.5[e]	3.5[f]	3.4[e]	3.4[e]
RSD[c]		1.12	1.07	1.05	1.03

[a]Consumer attributes were evaluated using a 5-point hedonic, end-anchored sensory scale where 1=dislike extremely and 5=like extremely.
[b]P-value from the Analysis of Variance table.
[c]RSD=Residual Standard Deviation from the Analysis of Variance table.
[ghi]Least squares means within a column and a trait lacking a common superscript differ (P < .05).

Table 7. Least squares means for consumer sensory traits[a] as effected by predetermined categories of lipid, Warner-Bratzer shear force, and pH from inside ham chops from the U.S. Pork Consumer Sensory Study.

Trait	n	Juiciness	Tenderness	Flavor	Like
pH Category		.0001[c]	.0002	.036	.0024
1 Low	646	3.2[d]	3.1[d]	3.2[d]	3.1[d]
2 Medium	614	3.3[e]	3.2[d]	3.2[de]	3.1[d]
3 High	506	3.5[f]	3.4[e]	3.3[e]	3.3[e]
RSD[c]		1.11	1.13	1.07	1.06
Lipid Category		.77	.53	.97	.80
1	427	3.1	3.2	3.2	3.2
2	854	3.3	3.2	3.2	3.1
3	485	3.3	3.2	3.2	3.2
RSD[c]		1.11	1.14	1.08	1.06
Shear Category		.07	.0352	.32	.23
1	382	3.3	3.1[d]	3.2	3.1
2	843	3.3	3.2[de]	3.3	3.2
3	517	3.4	3.3[e]	3.3	3.2
RSD[c]		1.1	1.14	1.08	1.06

[a]Consumer attributes were evaluated using a 5-point hedonic, end-anchored sensory scale where 1=dislike extremely and 5=like extremely.
[b] P-value from the Analysis of Variance table.
[c] RSD=Residual Standard Deviation from the Analysis of Variance table.
[e] Lipid categories: 1 Low = trained sensory scores ≤ 1.99; 2 Medium = trained sensory scores of 2.00 to 2.99; 2 High = trained sensory scores of 3.00 to 3.99; Intense = trained sensory scores of ≥ 4.00.
[f] Shear categories: 1 High = trained sensory scores ≤ 1.99; 2 Medium = trained sensory scores of 2.00 to 2.99; 3 Low = trained sensory scores of 3.00 to 3.99.
[def] Least squares means within a column and a trait lacking a common superscript differ (P < .05).

Table 8. Least squares means for quality measurements from loins (n=162) 24 hours postmortem in the 10th rib lean.

Quality measurement	Mean	Standard Deviation	Minimum	Maximum
pH	5.674	0.167	5.33	6.37
NPPC subjective color score[a]	3.3	0.87	1	5
Japanese subjective color score[b]	3.6	1.02	1	6
NPPC subjective firmness score[c]	3.4	0.95	1	5
Marbling score[d]	3.5	1.02	1	5
Minolta 50 mm reflectance	20.54	3.16	13.00	35.25
Minolta 50 mm CIE L*	45.08	3.23	36.05	56.56
Minolta 50 mm CIE a*	15.71	0.91	13.35	18.13
Minolta 50 mm CIE b	5.06	0.90	3.06	7.97
Minolta 8 mm reflectance	20.78	4.11	14.60	34.36
Minolta 8 mm CIE L*	45.40	4.35	37.80	58.61
Minolta 8 mm CIE a*	6.87	1.62	4.04	14.10
Minolta 8 mm CIE b*	4.22	1.45	1.39	10.67
HunterLab Miniscan CIE L*	42.43	3.19	35.30	55.60
HunterLab Miniscan CIE a*	-0.95	0.86	-2.90	2.20
HunterLab Miniscan CIE b*	6.06	1.43	3.30	12.80

[a]National Pork Producers Council fresh meat color score where 1=very pale, light pink and 5=very dark red.
[b]Japanese color scores where 1=very pale, light pink and 6=very dark red.
[c]National Pork Producers Council fresh meat firmness scores where 1=very soft and 5=very firm.
[d]National Pork Producers Council marbling scores where 1 = Devoid to Practically Devoid and 5 = Moderately Abundant or Greater.

Table 9. Mean, standard deviation, minimum and maximum values for chemical lipid (%), instrumental measurements of tenderness and sensory characteristics of pork loins from the Japanese Pork Consumer Study.

Quality measurement	Mean	Standard Deviation	Minimum	Maximum
Lipid, %	2.41	1.241	0.31	6.63
Warner-Bratzler shear force, kg	1.54	0.363	.71	3.11
Instron star-probe shear force, kg	2.40	0.381	1.50	3.58
Sensory[a]				
Juiciness	6.20	1.619	2.33	9.67
Tenderness	6.65	2.024	1.00	10.00
Chewiness	3.00	1.909	1.00	10.00
Flavor intensity	1.43	0.619	1.00	4.33
Off-flavor intensity	2.40	1.520	1.00	8.67

[a]Based on 10 point scales where 1 = extremely dry, extremely tough, very low chewiness or connective tissue, low flavor intensity and very low off-flavor, respectively and 10 = extremely juicy, extremely tender, extremely chewy or high connective tissue, extremely intense flavor and extremely intense off-flavor, respectively.

Table 10. Least squares means for consumer sensory scores segmented by Japanese color scores.

Consumer Attribute	Japanese Color Score[c] 1	2	3	4	5	6	P Value
	Blade-end Lean Japanese Color Score Values						
Aroma Like/Dislike [a]	3.00	3.17	3.20	3.19	3.18	3.48	0.16
Juiciness Like/Dislike [a]	2.51^{d}	3.07^{e}	3.12^{e}	3.18^{e}	3.07^{e}	3.04^{e}	0.0145
Tenderness Like/Dislike [a]	3.05	3.25	3.28	3.38	3.39	3.60	0.16
Flavor Like/Dislike [a]	2.85	3.19	3.19	3.22	3.21	3.37	0.23
Overall Taste Like/Dislike [a]	2.69^{d}	3.16^{e}	3.17^{e}	3.23^{e}	3.23^{e}	3.40^{e}	0.035
Appearance Like/Dislike [a]	2.87	2.95	3.25	3.11	3.07	3.15	0.11
Color Like/Dislike [a]	2.79^{d}	3.16^{e}	3.30^{e}	3.16^{e}	3.09^{e}	3.06^{de}	0.03
Color Intensity [b]	2.51^{d}	3.02^{e}	3.25^{f}	3.20^{ef}	3.34^{f}	3.46^{f}	0.001
Amount of Fat Like/Dislike [a]	2.95	3.09	3.29	3.16	3.16	3.19	0.29
Overall Visual Like/Dislike [a]	2.64^{d}	3.00^{e}	3.24^{f}	3.10^{ef}	3.11^{ef}	3.21^{ef}	0.008
	10th rib Lean Japanese Color Score Values						
Aroma Like/Dislike [a]	2.87	3.13	3.21	3.19	3.23	3.50	0.21
Juiciness Like/Dislike [a]	2.83	2.88	3.11	3.14	3.05	3.25	0.26
Tenderness Like/Dislike [a]	3.29^{de}	3.02^{d}	3.33^{e}	3.41^{e}	3.37^{e}	3.75^{e}	0.03
Flavor Like/Dislike [a]	3.04	3.01	3.20	3.2	3.17	3.40	0.33
Overall Taste Like/Dislike [a]	2.87	2.94	3.20	3.26	3.22	3.45	0.07
Appearance Like/Dislike [a]	2.54	3.02	3.11	3.14	3.13	3.35	0.06
Color Like/Dislike [a]	2.67^{d}	3.02^{de}	3.18^{e}	3.23^{e}	3.09^{e}	3.15^{e}	0.0469
Color Intensity [b]	2.50^{d}	2.88^{e}	3.04^{e}	3.33^{f}	3.51^{f}	3.60^{f}	0.001
Amount of fat Like/Dislike [a]	2.83	3.08	3.18	3.19	3.25	3.10	0.39
Overall Visual Like/Dislike[a]	2.46^{d}	2.91^{e}	3.11^{ef}	3.18^{f}	3.16^{f}	3.25^{f}	0.0023

[a] Consumer attributes were evaluated using a 5-point scale where 1=dislike extremely and 5=like extremely.
[b] Consumer attributes were evaluated using a 5-point scale where 1=light and 5=dark.
[c] Japanese color scores where 1=very pale, light pink and 6=very dark red.
[def] Least squares means within a row lacking a common superscript differ (P < .05).

Table 11. Least squared means for consumer sensory scores segmented by NPPC Color Scores.

Consumer Attribute[a]	NPPC Color Score[c] 1	2	3	4	5	P Value
	Blade-end Lean NPPC Color Score Values					
Aroma Like/Dislike [a]	3.02	3.19	3.22	3.14	3.29	.24
Juiciness Like/Dislike [a]	2.60^{d}	2.94^{de}	3.10^{f}	3.05^{ef}	3.14^{ef}	.004
Tenderness Like/Dislike [a]	3.10^{d}	3.18^{d}	3.41^{f}	3.28^{de}	3.51^{e}	.03
Flavor Like/Dislike [a]	2.92	3.10	3.25	3.16	3.30	.15
Overall Taste Like/Dislike [a]	2.75^{d}	3.12^{e}	3.26^{e}	3.13^{e}	3.35^{e}	.008
Appearance Like/Dislike [a]	2.85	3.03	3.18	3.06	3.17	.19
Color Like/Dislike [a]	2.83	3.15	3.23	3.14	3.12	.13
Color Intensity [b]	2.60^{d}	3.01^{e}	3.21^{f}	3.24^{f}	3.40^{g}	.0001
Amount of Fat Like/Dislike [a]	2.90	3.14	3.24	3.14	3.22	.23
Overall Visual Like/Dislike [a]	2.65^{d}	3.06^{e}	3.15^{e}	3.11^{e}	3.18^{e}	.02
	10th rib Lean NPPC Color Score Values					
Aroma Like/Dislike [a]	2.84	3.19	3.23	3.17	3.27	.13
Juiciness Like/Dislike [a]	2.75^{d}	2.96^{de}	3.15^{e}	3.02^{de}	3.26^{e}	.05
Tenderness Like/Dislike [a]	2.91^{d}	3.22^{de}	3.36^{e}	3.3^{e}	3.72^{f}	.004
Flavor Like/Dislike [a]	2.87	3.09	3.22	3.21	3.31	.24
Overall Taste Like/Dislike [a]	2.72^{d}	3.04^{de}	3.22^{ef}	3.21^{ef}	3.38^{f}	.02
Appearance Like/Dislike [a]	2.47^{d}	3.14^{e}	3.10^{e}	3.16^{e}	3.21^{e}	.004
Color Like/Dislike [a]	2.56^{d}	3.13^{e}	3.18^{e}	3.18^{e}	3.13^{e}	.008
Color Intensity [b]	2.53^{d}	2.91^{e}	3.13^{f}	3.41^{g}	3.66^{h}	.0001
Amount of fat Like/Dislike [a]	2.84	3.10	3.15	3.25	3.25	.13
Overall Visual Like/Dislike [a]	2.44^{d}	2.99^{e}	3.12^{e}	3.20^{e}	3.18^{e}	.0003

[a] Consumer attributes were evaluated using a 5-point scale where 1=dislike extremely and 5=like extremely.
[b] Consumer attributes were evaluated using a 5-point scale where 1=light and 5=dark.
[c] National Pork Producers Council fresh meat color score where 1=very pale, light pink and 5=very dark red.
[defgh] Least squares means within a row lacking a common superscript differ (P < .05).

Table 12. Least squares means for sonsumer sensory scores segmented by NPPC marbling scores.

Consumer Attribute	NPPC Marbling Score[c] 1	2	3	4	5	6	P Value
Blade-end Lean NPPC Marbling Score Values							
Aroma Like/Dislike[a]	3.05[de]	3.04[d]	3.23[e]	3.28[e]	3.26[e]	-	.03
Juiciness Like/Dislike[a]	2.89[d]	2.89[d]	3.12[d]	3.21[d]	3.13[d]	-	.03
Tenderness Like/Dislike[a]	3.22	3.16	3.41	3.39	3.45	-	.09
Flavor Like/Dislike[a]	3.06[de]	2.98[d]	3.24[e]	3.33[e]	3.26[e]	-	.008
Overall Taste Like/Dislike[a]	2.97[de]	2.97[d]	3.24[ef]	3.37[f]	3.19[def]	-	.002
Appearance Like/Dislike[a]	2.86[d]	2.96[d]	3.08[d]	3.28[e]	3.48[e]	-	.001
Color Like/Dislike[a]	2.92[d]	3.10[d]	3.10[d]	3.30[e]	3.45[e]	-	.01
Color Intensity[b]	2.86[d]	3.15[de]	3.24[e]	3.31[e]	3.22[e]	-	.05
Amount of Fat Like/Dislike[a]	2.75[d]	3.08[de]	3.20[e]	3.26[e]	3.42[e]	-	.01
Overall Visual Like/Dislike[a]	2.64[d]	2.92[e]	3.11[e]	3.27[f]	3.45[f]	-	.0001
10[th] rib Lean NPPC Marbling Score Values							
Aroma Like/Dislike[a]	3.20	3.11	3.16	3.27	3.87	3.00	.13
Juiciness Like/Dislike[a]	3.09[de]	3.00[d]	3.01[de]	3.13[de]	4.12[e]	3.36[de]	.048
Tenderness Like/Dislike[a]	3.34	3.29	3.25	3.39	4.25	3.82	.07
Flavor Like/Dislike[a]	3.15[d]	3.19[d]	3.14[d]	3.29[d]	4.12[e]	3.64[de]	.04
Overall Taste Like/Dislike[a]	3.15[d]	3.16[d]	3.12[d]	3.34[de]	4.25[f]	3.82[ef]	.006
Appearance Like/Dislike[a]	3.01[d]	3.11[de]	3.19[de]	3.32[de]	3.75[e]	2.82[d]	.02
Color Like/Dislike[a]	3.07[d]	3.17[d]	3.23[de]	3.28[de]	3.87[e]	2.82[d]	.04
Color Intensity[b]	3.16[d]	3.36[de]	3.15[d]	3.25[a]	3.87[e]	2.91[d]	.02
Amount of Fat Like/Dislike[a]	3.06[d]	3.19[de]	3.26[e]	3.36[e]	3.75[e]	3.09[de]	.02
Overall Visual Like/Dislike[a]	3.00[d]	3.13[d]	3.23[d]	3.34[d]	3.50[d]	2.82[d]	.009

[a] Consumer attributes were evaluated using a 5-point scale where 1=dislike extremely and 5=like extremely.
[b] Consumer attributes were evaluated using a 5-point scale where 1=light and 5=dark.
[c] National Pork Producers Council new fresh meat marbling scores where 1≤1% lipid, 2=2% lipid; 3=3% lipid, 4=4% lipid, 5=5% lipid and 6≥6% lipid.
[def] Least squares means within a row lacking a common superscript differ (P < .05).

Table 13. Least squares means for consumer sensory scores segmented by NPPC firmness scores

Consumer Attribute	NPPC Firmness Score[c] 1	2	3	4	5	P Value
Blade-end Lean NPPC Firmness Score Values						
Aroma Like/Dislike[a]	3.06	2.22	2.26	3.15	-	.08
Juiciness Like/Dislike[a]	3.02	3.07	3.16	2.94	-	.32
Tenderness Like/Dislike[a]	3.25	3.34	3.41	3.33	-	.42
Flavor Like/Dislike[a]	3.11	3.19	3.27	3.10	-	.29
Overall Taste Like/Dislike[a]	3.06	3.19	3.28	3.13	-	.12
Appearance Like/Dislike[a]	2.98	3.11	3.15	3.29	-	.13
Color Like/Dislike[a]	3.04	3.17	3.18	3.23	-	.29
Color Intensity[b]	2.99[d]	3.20[e]	3.36[f]	3.27[ef]	-	.0001
Amount of Fat Like/Dislike[a]	3.05	3.23	3.19	3.21	-	.24
Overall Visual Like/Dislike[a]	2.91[d]	3.16[e]	3.13[e]	3.42[e]	-	.001
10[th] rib Lean NPPC Firmness Score Values						
Aroma Like/Dislike[a]	3.18	3.12	3.17	3.27	3.03	.13
Juiciness Like/Dislike[a]	3.09[e]	2.92[de]	3.09[e]	3.18[e]	2.79[d]	.026
Tenderness Like/Dislike[a]	3.45[e]	3.29[de]	3.31[de]	3.44[e]	3.08[d]	.05
Flavor Like/Dislike[a]	3.20	3.00	3.17	3.29	3.05	.10
Overall Taste Like/Dislike[a]	3.09	3.04	3.17	3.29	3.09	.24
Appearance Like/Dislike[a]	2.89[d]	3.20[de]	3.00[d]	3.19[de]	3.26[e]	.03
Color Like/Dislike[a]	2.91	3.18	3.10	3.20	3.28	.15
Color Intensity[b]	2.73[d]	2.88[d]	3.17[e]	3.34[f]	3.37[f]	.0001
Amount of fat Like/Dislike[a]	2.98	3.14	3.12	3.23	3.30	.24
Overall Visual Like/Dislike[a]	2.75[d]	3.31[de]	3.04[de]	3.19[e]	3.30[e]	.005

[a] Consumer attributes were evaluated using a 5-point scale where 1=dislike extremely and 5=like extremely.
[b] Consumer attributes were evaluated using a 5-point scale where 1=light and 5=dark.
[c] National Pork Producers Council fresh meat firmness scores where 1=very soft and 5=very firm.
[def] Least squares means within a row lacking a common superscript differ (P < .05).

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Table 14. Least squares means for consumer sensory scores segmented by pH, Instron and lipid categories.

Consumer Attribute	pH category using[b]	1 Low	2 Medium	3 High	P Value
Aroma Like/Dislike[a]		3.14	3.22	3.23	.33
Juiciness Like/Dislike[a]		2.97^{e}	3.14^{f}	3.17^{f}	.04
Tenderness Like/Dislike[a]		3.23^{e}	3.35^{ef}	3.49^{f}	.01
Flavor Like/Dislike[a]		3.09	3.24	3.28	.06
Overall Taste Like/Dislike[a]		3.09^{e}	3.21^{ef}	3.30^{f}	.05
Appearance Like/Dislike[a]		3.03	3.16	3.13	.23
Color Like/Dislike[a]		3.10	3.22	3.14	.24
Color Intensity[a]		3.05^{e}	3.23^{f}	3.40^{g}	.0001
Amount of Fat Like/Dislike[a]		3.13	3.18	3.21	.58
Overall Visual Like/Dislike[a]		3.02	3.15	3.18	.08
	Instron star-probe shear force category[c]	1 Tough	2 Medium	3 Tender	P Value
Aroma Like/Dislike[a]		3.11	3.19	3.27	.09
Juiciness Like/Dislike[a]		2.98^{e}	2.98^{e}	3.29^{g}	.0002
Tenderness Like/Dislike[a]		3.15^{e}	3.24^{e}	3.63^{g}	.0001
Flavor Like/Dislike[a]		3.18^{ef}	3.11^{e}	3.30^{f}	.05
Overall Taste Like/Dislike[a]		3.13^{e}	3.13^{e}	3.33^{f}	.02
Appearance Like/Dislike[a]		3.17	3.05	3.11	.40
Color Like/Dislike[a]		3.16	3.16	3.14	.92
Color Intensity[a]		3.15^{e}	3.16^{e}	3.33^{f}	.02
Amount of fat Like/Dislike[a]		3.21	3.15	3.17	.78
Overall Visual Like/Dislike[a]		3.11	3.11	3.12	.99
	Lipid category[d]	1 Low	2 Medium	3 High	P Value
Aroma Like/Dislike[a]		3.22	3.14	3.23	.34
Juiciness Like/Dislike[a]		3.15	3.00	3.13	.16
Tenderness Like/Dislike[a]		3.45^{f}	3.23^{e}	3.37^{ef}	.04
Flavor Like/Dislike[a]		3.18	3.17	3.25	.57
Overall Taste Like/Dislike[a]		3.21	3.13	3.26	.28
Appearance Like/Dislike[a]		3.03^{e}	3.08^{ef}	3.22^{f}	.05
Color Like/Dislike[a]		3.04^{e}	3.16^{ef}	3.26^{f}	.03
Color Intensity[a]		3.21	3.25	3.19	.73
Amount of fat Like/Dislike[a]		3.05^{e}	3.17^{ef}	3.31^{f}	.004
Overall Visual Like/Dislike[a]		3.03^{e}	3.07^{e}	3.23^{f}	.02

[a] Consumer attributes were evaluated using a 5-point scale where 1=dislike extremely and 5=like extremely.or for color intensity 1=light and 5=dark.
[b]pH category in the 10[th] rib longissimus muscle where 1 = low pH (less than 5.6); 2 = medium pH (5.6 to 5.75); and 3 = high pH (greater than 5.75).
[c]Instron star-probe category where 1 = tough (greater than 2.59 kg); 2 = medium (2.59 to 2.27 kg); and 3 = tender (less than 2.27 kg).
[d] Lipid category where 1 = low lipid (less than 1.75%); 2 = medium lipid (3.0 to 1.75%); and 3 = high lipid (greater than 3.99%).
[efg] Least squares means within a row lacking a common superscript differ ($P < .05$).