CONSISTENCY IN MEAT QUALITY

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Introduction

Establishing an understanding of factors that drive consumer acceptance of pork is inherently important to maintaining the competitiveness of pork. It is obvious that if the pork industry produces an end-product that is not acceptable to consumers, consumer will utilize their purchasing dollars for other protein sources. *So,what are the important factors or quality characteristics that impact consumer acceptance of pork?* Pork quality traits or factors that affect consumer acceptance have, in general, been classified 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 water holding capacity or drip loss, lean color, pH (as it relates to drip loss and color), and intramuscular lipid or marbling. 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. 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. These quality traits have been well accepted as being important characteristics that drive consumer acceptance.

It is well known that variation in visual and eating quality characteristics are found in the pork industry**.** The National Pork Quality Project was conducted to determine if chilled pork carcasses could be accurately and practically evaluated for quality variation (Kauffman et al., 1997), but they also evaluated the level or percentage of quality defects. 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). These were Undesirable quality classes. Within individual plants, the percentage of PSE plus RSE ranged from 16% to 58% and two plants did not have any PSE.

It is obvious from this study 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 result in increased demand for U.S. pork?* To begin to answer this question, data from a large consumer sensory study conducted in the U.S. will be used to examine the relationship between quality classifications of pork and consumer acceptance. Additionally, the relationship between quality and consumer intent to purchase will be discussed.

Relationship of Quality Traits to U.S. Consumer Acceptance

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 10^{th} 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 1) 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 2) and the fresh inside ham chops (Table 3). For loin chops, consumer sensory responses differed by pH category and shear category, but consumer sensory responses did not differ as intramuscular lipid percentage

Table 1. 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
<u>City</u>	.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]
<u>Cut</u>	.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]
<u>City x Cut</u>	.0001	.0001	.0001	.0001
Denver x Chicken	3.5[f]	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.

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 or tenderness affected consumer perceptions. 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.

Table 2. 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 ($P < .05$).

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 3). 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.

Table 3. 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 ($P < .05$).

These results show that consumers can detect differences in pork eating quality as pH and tenderness, as measured by shear force, differ. *While this is very important, it is only important if detection of these eating quality differences impacts consumers' intent to purchase or the price* *that they are willing to pay for pork.* Therefore, the data from this study were used to examine this question.

Relationship of Quality Traits to Consumer Intent to Purchase

Consumers were also asked a purchase question. It was: "Suppose the piece of meat you just tasted were available in your local supermarket. The price per pound is *x*. Thinking about the ***taste*** and ***price*** of the meat you just tasted, how likely would you be to buy it?" Consumers answered this question by marking very unlikely (0) to very likely (4) using a 5 point scale. Five retail prices were randomly assigned to either boneless loin or fresh ham chops. For the loin cuts the prices ($/lb) were $1.99, $2.74, $3.49, $4.24, and $4.99. For ham, the prices ($/lb) were $1.61, $2.22, $2.80, $3.43, and $4.04. In addition, demographic data was collected. These data were used to determine the relationships between price, demographic information and meat quality characteristics. Also, these data were used to examine how changing meat quality characteristics impacted consumers intent to purchase.

To examine these relationships a statistical tool commonly used by economists was used. This model estimated the ordered Probit model for each sensory attribute and for the buying question. However, just estimating the model was not sufficient to answer all questions. Therefore, other approaches were used that accounted for the relationship between the variables. The loin and ham results were analyzed separately.

Table 4 gives a list of consumer, demographic and chemical variables used in the loin and ham analysis. Several of the demographic variables are 'dummy variables' (i.e., 1 or 0 denoting education levels, health, city, ethnicity, and marriage). When working with dummy variables, the base category needs to be identified. The base category refers to demographic characteristics of those individuals for which all the dummy variables are zero. For this data set, the base category is defined to be a non-married male, living in Boston, not having any health problems influencing his diet, of some other ethnic origin than those listed, and with some post college education.

Loin Results

Table 5 gives the summary statistics for the variables used in the loin analysis.

For the sample, all three sensory attributes are ranked on average slightly above the midpoint of 3 on the 5 point. This suggests a slight leaning toward the 'strongly like' end of the scale for loin in terms of juiciness, tenderness, and flavor. The likelihood of buying the loin cut has an average value of 3, indicating no strong tendency one way or the other. In terms of demographics, the average participant is about 46 years old, with an income around $51,000,

Table 4. Variables and definitions for the consumer response, demographic and chemical measurements used in the economic analyses.

Variable	Definition
Age	Age of Participant in years
Education 1	1 if some high school or less, 0 otherwise
Education 2	1 if some education beyond high school, 0 otherwise
Education 3	1 if completed college, 0 otherwise
Income	Income level midpoint in dollars
No. Household	Number of household members
No. Children	Number of children less than 18 years old
Health 1	1 if household member has a health problem affecting diet, 0 otherwise
City 3	1 if city is Denver, 0 otherwise
City 4	1 if city is Chicago, 0 otherwise
Gender	1 if female, 0 otherwise
Ethnic 1	1 if Caucasian, 0 otherwise
Ethnic 2	1 if African American, 0 otherwise
Ethnic 3	1 if Hispanic, 0 otherwise
Ethnic 4	1 if Asian, 0 otherwise
Married	1 if married or domestic partnership, 0 otherwise
Order	1 if cut is first tasted, 0 if second
Shear	Kg force required to segment a core of cut
Drip loss	Amount of moisture loss in a 24 hr. period from a (2.54 cm) meat cube at stored at 4 degrees Celsius
Percent fat	Percentage of fat of cut using petroleum ether for 18 hours with Soxhlet apparatus
pH level	pH level measured as the negative log of the hydrogen ion concentration in cut
Cook time	Total time in minutes required to cook the meat to internal temperature of 72°C
Cook temperature	Beginning internal temperature in °C of cut when cooking began
Price	Price in dollars per pound

with 3 people in the household. The means of the dummy variables indicated that the percentage of the sample with those characteristics or about 80% of the participants have at least a high school education, 86% have no health problems, 40% are female, 71% married, and 93%

Caucasian. All three cities are represented roughly the same, with each accounting for about 33% of the sample.

Table 5. Summary statistics for the loin (n = 1102).

Variable	Mean	Std. Dev.	Range
Juiciness	3.380	1.158	1 – 5
Tenderness	3.352	1.087	1 – 5
Flavor	3.324	1.052	1 – 5
Buy	2.966	1.341	1 – 5
Age	46.431	14.298	19 – 81
Education 1	0.030	0.171	0, 1
Education 2	0.554	0.497	0,1
Education 3	0.263	0.441	0,1
Income	50989.110	22821.460	7500 – 87500
No. Household	2.907	1.401	0 – 7
No. Children	0.836	1.179	0 – 5
Health 1	0.145	0.352	0
City 3	0.340	0.474	0,1
City 4	0.319	0.466	0,1
Gender	0.403	0.491	0,1
Ethnic 1	0.924	0.265	0,1
Ethnic 2	0.028	0.165	0,1
Ethnic 3	0.029	0.168	0,1
Ethnic 4	0.005	0.074	0,1
Married	0.713	0.452	0,1
Order	0.525	0.500	0,1
Shear	6.262	1.933	2.3 – 14.26
Drip	0.027	0.021	0.0026 – .119
Percent fat	2.596	1.343	0.28 – 7.92
Ph level	5.843	0.393	0 – 6.96
Cook time	12.230	5.038	4 – 74
Cook temperature	8.021	5.938	3.2 – 82
Price	3.519	1.052	1.99 – 4.99

Table 6 gives the results of the ordered probit model for the hypothetical purchase or buy decision for loin cuts. The buy model does *not* include the sensory attributes and this warrants some discussion. As was seen in the juiciness, tenderness, and flavor models, they depend on the

Table 6. Order Probit for loin for the intent to buy question.

			Marginal Effects			
Variable	**Estimate**	**P-Value**	**Low**	**P-Value**	**High**	**P-Value**
Intercept	1.920	.009				
Age	0.003	.232	-0.001	0.233	0.001	0.232
Education 1	0.269	.257	-0.067	0.256	0.059	0.259
Education 2	0.127	.234	-0.032	0.235	0.028	0.235
Education 3	0.195	.085	-0.049	0.086	0.043	0.085
Income	0.000	.800	0.000	0.800	0.000	0.800
No. household	0.030	.529	-0.008	0.529	0.007	0.529
No. children	-0.006	.905	0.002	0.905	-0.001	0.905
Health	0.190	.039	-0.047	0.039	0.041	0.040
City 3	0.086	.308	-0.021	0.308	0.019	0.311
City 4	-0.269	.002	0.067	0.002	-0.059	0.002
Gender	0.049	.517	-0.012	0.516	0.011	0.519
Ethnic 1	0.069	.815	-0.017	0.815	0.015	0.815
Ethnic 2	-0.043	.908	0.011	0.908	-0.009	0.908
Ethnic 3	0.273	.439	-0.068	0.439	0.060	0.440
Ethnic 4	-0.349	.625	0.087	0.625	-0.076	0.625
Married	-0.155	.099	0.039	0.100	-0.034	0.100
Order	-0.056	.400	0.014	0.401	-0.012	0.400
Shear	-0.066	.000	0.017	0.000	-0.014	0.000
Drip	-4.431	.006	1.105	0.006	-0.967	0.006
Percent fat	-0.001	.965	0.000	0.965	0.000	0.965
pH level	0.034	.734	-0.008	0.734	0.007	0.734
Cook time	-0.001	.874	0.000	0.874	0.000	0.874
Cook temperature	0.001	.827	0.000	0.827	0.000	0.827
Price	-0.354	.000	0.088	0.000	-0.077	0.000
Threshold 1	0.645	.000				
Threshold 2	1.284	.000				
Threshold 3	2.067	.000				

characteristics of the meat cut, along with demographics. Consequently, these sensory attributes reflect or summarize the information in the meat characteristics, in addition to other factors. Similar to above, if the meat characteristics are included in the model *along with* the sensory attributes and the meat characteristics are not significant then this indicates that meat characteristics add no explanatory power to the model beyond the sensory attributes. We first checked this possibility and found that indeed the characteristics had no explanatory power beyond the sensory attributes. This implies then that the sensory attributes are capturing or summarizing all the variability due to the characteristics, as might be suspected. Now clearly a retailer or processor cannot control juiciness, tenderness, and flavor rankings directly but only indirectly through changing the meat characteristics. This suggests that the more appropriate model for inference is one in which the impact of the meat characteristics are not *implicitly* summarized through the sensory variables, but one where their impact is *explicitly* captured by including the meat characteristics and *not* including the sensory attributes, of course along with demographics.

The variables that are significantly different from zero in the buy model at the 10% significance level are education 3, health, city 4, married, shear, drip, and price. The interpretation focuses only on these statistically significant variables.

Marginal effects for loin cut buy If the consumer had more than a college degree then the probability that the consumer was very unlikely (likely) to purchase a loin cut decreased (increased) by .049 (.043). If the consumer had a health problem affecting their diet, then the probability that the consumer was very unlikely (likely) to purchase a loin cut decreased (increased) by .047 (.041). If the consumer was in Chicago then the probability that the consumer was very unlikely (likely) to purchase a loin cut increased (decreased) by .067 (.059). If the consumer was in the married category then the probability that the consumer was very unlikely (likely) to purchase a loin cut increased (decreased) by .039 (.034). If the shear level was increased by one unit then the probability that the consumer was very unlikely (likely) to purchase a loin cut increased (decreased) by .017 (.014). If the drip loss increased by one unit then the probability that the consumer was very unlikely (likely) to purchase a loin cut increased (decreased) by 1.105 (.967). Finally, as the price of the loin cut increases by one unit, then the probability that consumer was very unlikely (likely) to purchase a loin cut increased (decreased) by .088 (.077).

Marginal rates of substitution for meat characteristics in buy There were obviously three marginal rates of substitution of interest in the buy model: drip/shear, drip/price, and shear/price. The marginal rate of substitution between drip and shear was about –67, which means that if drip was increased by one unit then shear would have to be decreased by 67 units to keep the probabilities unchanged. The marginal rate of substitution between drip and prices was about –.08, which means that if price was increased by one unit then drip would have to be decreased by .08 units to keep the probabilities unchanged. The marginal rate of substitution between shear and prices was about –5.4, which means that if price was increased by one unit then shear would have to be decreased by 5.4 units to keep the probabilities unchanged. An alternative way to understand these last two would be to take the inverses: if drip was increased by one unit then price would have to be decreased by 125 dollars to keep the probabilities unchanged and if shear was increased by one unit then price would have to be decreased by .19 units to keep the probabilities unchanged. Clearly, price and drip are very important and changes in the drip level require large changes in prices to offset the drip changes.

Marginal Revenue for Meat Characteristics Using an average price of a loin of \$3.52 per pound, the marginal revenue associated with an additional unit of shear is $\$3.52 \times -.014 = -\$.05$ and the marginal revenue associated with drip is $\$3.52 \times -.967 = -\$3.40$. So increasing the shear factor by one unit cost about 5 cents whereas increasing the drip factor by one unit cost about 3.4 dollars.

Ham Results

The ham results were analyzed as discussed for the loin. Table 7 gives the summary statistics for the variables used in the ham analysis and as these data were very similar to that of loin data, the data will not be discussed.

Table 7. Summary statistics for the ham (n = 1028).

Variable	Mean	Std. Dev.	Minimum	Maximum
Buy	2.88619	1.37783	1	5
Age	46.58366	13.81904	19	81
Education 1	0.027237	0.16285	0	1
Education 2	0.56518	0.49598	0	1
Education 3	0.25584	0.43654	0	1
Income	51121.11	22931.76	7500	87500
No. Household	2.92315	1.41866	1	7
No. Children	0.85798	1.20824	0	5
Health 1	0.14591	0.35319	0	1
City 3	0.37451	0.48423	0	1
City 4	0.27529	0.44688	0	1
Shear	6.31006	1.79187	1.88	13.4
Drip	0.027396	0.021581	0.0026	0.119
Percent fat	5.4707	4.71016	0.91	70.71
Ph level	5.76863	0.26342	5.24	6.65
Cook time	13.36284	4.54745	5	57
Cook temperature	8.38307	3.52648	2.4	19
Order	0.49319	0.5002	0	1
Price	2.84042	0.84649	1.61	4.04
Juiciness	3.38035	1.14834	1	5
Tenderness	3.25097	1.13853	1	5
Flavor	3.28891	1.07607	1	5
Gender	0.39494	0.48908	0	1
Ethnic 1	0.93288	0.25035	0	1
Ethnic 2	0.019455	0.13819	0	1
Ethnic 3	0.029183	0.1684	0	1
Ethnic 4	0.005837	0.076211	0	1
Married	0.7179	0.45024	0	1

Table 8 gives the results of the ordered probit model for the hypothetical purchase or buy decision for ham cuts. As in the loin buy model, the ham buy model did *not* include the sensory attributes for the same reasons. The variables that were significantly different from zero at the 10% significance level were age, city 3, shear, drip, pH level, and price.

Table 8. Order Probit for ham for the intent to buy question.

			Marginal Effects			
Variable	**Estimate**	**P-Value**	**Low**	**P-Value**	**High**	**P-Value**
Intercept	-0.400	.664				
Age	0.008	.013	-0.002	0.014	0.002	0.014
Education 1	0.245	.352	-0.067	0.351	0.057	0.353
Education 2	-0.042	.705	0.012	0.705	-0.010	0.705
Education 3	0.050	.670	-0.014	0.671	0.011	0.670
Income	0.000	.952	0.000	0.952	0.000	0.952
No. household	-0.004	.941	0.001	0.941	-0.001	0.941
No. children	0.076	.196	-0.021	0.195	0.018	0.198
Health	0.153	.127	-0.042	0.127	0.036	0.129
City 3	0.234	.013	-0.064	0.013	0.054	0.014
City 4	0.135	.171	-0.037	0.170	0.031	0.173
Gender	0.095	.210	-0.026	0.209	0.022	0.213
Ethnic 1	0.285	.319	-0.078	0.319	0.066	0.319
Ethnic 2	0.387	.334	-0.106	0.334	0.090	0.335
Ethnic 3	0.512	.194	-0.140	0.193	0.118	0.196
Married	-0.147	.145	0.040	0.145	-0.034	0.146
Order	0.051	.455	-0.014	0.456	0.012	0.454
Shear	-0.060	.003	0.016	0.002	-0.014	0.003
Drip	-2.901	.075	0.792	0.075	-0.672	0.078
Percent fat	0.009	.380	-0.003	0.379	0.002	0.383
pH level	0.312	.029	-0.085	0.030	0.072	0.029
Cook time	-0.014	.054	0.004	0.054	-0.003	0.056
Cook temperature	0.017	.183	-0.005	0.183	0.004	0.184
Price	-0.402	.000	0.110	0.000	-0.093	0.000
Threshold 1	0.6623	.000				
Threshold 2	1.285	.000				
Threshold 3	1.194	.000				

*Marginal effects for ham cut buy For every additional year the probability that the consumer is very unlikely (likely) to bu*y the cut decreased (increased) by -.002 (.002). If the consumer was in Denver, then the probability that the consumer was very unlikely (likely) to purchase ham decreased (increased) by .064 (.054). If the shear level was increased by one unit then the probability that the consumer was very unlikely (likely) to purchase a ham cut increased (decreased) by .016 (.014). If the drip level was increased by one unit then the probability that the consumer was very unlikely (likely) to purchase a ham cut increased (decreased) by .792 (.672). If the pH level was increased by one unit then the probability that the consumer was very unlikely (likely) to purchase a ham cut decreased (increased) by .085 (.072). If the cook time was increased by one unit then the probability that the consumer was very unlikely (likely) to purchase a ham cut increased (decreased) by .004 (.003). Finally, as the price of the ham cut increased by one unit, then the probability that consumer was very unlikely (likely) to purchase a ham cut increased (decreased) by .110 (.093).

Marginal rates of substitution for meat characteristics in buy. There were ten marginal rates of substitution that may be of interest in the ham buy model as listed below:

Marginal rate of substitution	Value
Shear/Drip	–.02
Shear/Ph level	.19
Cook time/Shear	–.23
Shear/Price	–.15
pH level/Drip	.11
Cook time/Drip	–.01
Drip/Price	–7.22
Cook time/Ph level	.05
pH level/Price	.77
Cook time/Price	–.04

Focusing on variables involving price, the effects indicated the following. If shear was increased by one unit then price would have to decrease by 15 cents to leave the probabilities unchanged (obviously beyond the range of the data). If drip loss was increased by one unit then price would have to be decreased by 7.22 dollars to leave the probabilities unchanged. If pH level was increased by one unit then price would have to be increased by 77 cents before the probabilities would change. If cook time increased by one unit then price would have to be decreased by 4 cents. These results indicated that what the consumer is willing to pay is very sensitive to the level of drip loss in the ham cut.

Marginal Revenue for Meat Characteristics As in the loin analysis, an average price of a ham of $2.84 per pound was be used to calculate the marginal revenue associated with an additional unit of shear, drip, pH level, and cook time, respectively: $2.84 × –.014 = –$.04 (shear), $2.84 × –.672 = –$1.91 (drip), $2.84 × .072 = $.20 (Ph level), and $2.84 × –.003 = –$.01 (cook time). So similar to loin, the mostly costly change is in drip loss.

Summary and Conclusions for the intent to purchase

Analyzing three sensory attribute measures (juiciness, tenderness, and flavor), six meat characteristics (shear, drip, percent fat, pH level, cook time, cook temperature) and several demographic variables with an ordered probit model these question were answered for loin cuts and ham cuts.

With respect to the variable categories, in every model where they are included, the sensory attributes show up as significant. With respect to the demographic variables, no real discernible pattern emerges across models, though in each model some type of demographic variable was significant. In terms of the meat characteristics, shear and drip appear in the most models as being significant, though others are significant in some specific models.

Marginal rates of substitution between characteristics (i.e., tradeoffs) were calculated, where appropriate. In general most of the marginal rates of substitution were relatively small (less than 1 in absolute value) indicating that a characteristic could be altered without having to make drastic changes in other characteristics. However, there is one notable exception to this general rule. The marginal rate of substitution between price and drip was always greater 1 in absolute value in the buy decision, indicating that people are very sensitive to changes in drip in terms of how much they would be willing to pay. Specifically, if drip increases by one unit in the loin (ham) cuts then people must be compensated with a $12.5 ($7.22) per pound price drop in loin (ham).

Finally, in terms of the value of the characteristics, shear and drip only have value in the loin cuts and it was calculated that for a unit decrease in shear and drip, the increase in revenue would be $.05 and $3.40. For ham several characteristics had value. For a one unit increase in shear, drip, pH level, and cook time (individually) then revenue would change by a – $.04, – $1.91, $.20, and – $.01, respectively. Clearly, drip loss had the largest economic impact of any of the characteristics.

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 9; 10th rib characteristics only). Additionally, pork loins varied in lipid, shear force and trained meat descriptive sensory attributes (Table 10). 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.

Table 9. 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 10. 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.

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 11; 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 score 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

Table 11. Least squares means for consumer sensory scores segmented by Japanese color scores.

	Japanese Color Score[c]						
Consumer Attribute	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 ($P < .05$).

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.

Table 12. 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 ($P < .05$).

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 12). 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 13). 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 14. 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

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

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
	10th 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 ($P < .05$).

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

Table 14. Least squares means for consumer sensory scores segmented by NPPC firmness scores

	NPPC Firmness Score[c]					
Consumer Attribute	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 ($P < .05$).

acceptability, least squares means from Japanese consumer categories were evaluated (Table 15). 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

Table 15. 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 10th 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 ($P < .05$).

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.

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