Final Report

Evaluation of the contribution of tenderness, juiciness, and flavor to the overall consumer beef eating experience

Submitted to the Angus Foundation
St. Joseph, MO

September 2016

Department of Animal Sciences and Industry, Kansas State University, Manhattan, KS 66506

Phone: (785) 532-3469
E-mail: travisoquinn@ksu.edu

Principal Investigator: T. G. O'Quinn

Introduction

Overall beef palatability can be attributed to three primary traits - tenderness, juiciness, and flavor (Smith and Carpenter, 1974). It has been widely documented that consumers are willing to pay premiums for beef that will repeatedly and consistently meet their eating expectations (Shackelford et al., 2001; Lyford et al., 2010). Countless studies over the past eight decades have evaluated the impact of various animal production factors (breed, genetics, diet, animal health, growth-promotant use, animal age, handling stress, etc.) and meat production and processing factors (USDA quality grade, marbling, aging, electrical stimulation, chilling methods, carcass suspension method, product enhancement, etc.) on these traits. As a result, a greater understanding is known today about the factors impacting beef eating quality than ever before. Much of this research has resulted in industry-wide changes to production practices, as well as the development of new technology aimed at improving beef eating quality and consumer satisfaction.

Multiple authors have worked to identify which of these palatability traits contributes the most to overall eating satisfaction. These studies have historically identified tenderness as the most important palatability trait (Savell et al., 1987; Miller et al., 1995a; Savell et al., 1999; Egan et al., 2001). Results of the first three National Beef Quality Audits in 1991, 1995, and 2000 identified beef tenderness as one of the most important quality challenges facing the beef industry (Smith et al., 1992; Boleman et al., 1998; McKenna et al., 2002). As a result, much industry research over the past 20 years has focused on tenderness improvement. Results of the most recent published Beef Tenderness survey showed that over 94% of beef from the rib and loin in foodservice and at the retail level would be classified as “tender” or “very tender” (Guelker et al., 2013). As a result of industry improvements in beef tenderness, more recent investigations have most commonly shown “flavor” to be the largest factor impacting overall beef eating satisfaction (Killinger et al., 2004; O'Quinn et al., 2012; Corbin et al., 2015; Lucherk et al., 2016).

Regardless, such inferences about a single palatability trait’s impact on beef eating quality are oversimplified. Overall beef eating quality is dependent upon all three factors – tenderness, juiciness, and flavor – as well as the interaction among these traits. Beef steaks may excel at one or even two of these traits, yet fail to meet consumer eating expectations due to the unsatisfactory level of another trait. Conversely, a steak may be deemed acceptable by consumers due primarily to the outstanding level of a single trait despite the lower and even unacceptable levels of one or both of the other traits. To date, no comprehensive study has evaluated this interaction among palatability traits and assessed the relative risk of an unacceptable overall eating experience associated with the failure of a single or combination of palatability traits.

It was therefore the objective of this report to combine the consumer palatability data collected over the past 5 years as a result of a series of trials that have evaluated the palatability traits of a diverse set of treatments in order to evaluate the relative contribution of tenderness, juiciness, and flavor to overall consumer eating satisfaction.

Methods

Over the past 5 years, a number of consumer studies (Table 1) have been conducted evaluating beef palatability. The beef samples in these studies were from a wide range of treatments representing a large diversity of beef eating quality levels. Most of these studies have included a diversity of USDA quality grades, as well as differences in muscle, degree of doneness, enhancement level, finishing diet, and animal maturity. Together, this group of samples represented a large variation in beef eating quality and interactions among tenderness, juiciness, and flavor acceptability.

Within each study, the same 100 mm line scales were used for consumer evaluation of steak tenderness, juiciness, flavor, and overall liking. Scales were anchored as extremely tough/dry/dislike extremely at the 0 end point and extremely tender/juicy/like extremely at the 100 end point. Additionally, consumers rated each trait as either acceptable or unacceptable (yes/no), providing definitive consumer perceptions of steak acceptability for each trait. All samples used in these studies were cooked using similar dry-heat grilling procedures. Collectively, these studies used more than 1,800 beef consumers from multiple regions of the U.S. and included 1,505 unique samples resulting in more than 12,000 individual consumer observations. This large number of consumer observations utilizing the same scaling and similar testing procedures represented a unique opportunity for a robust analysis evaluating the contribution of the three most important palatability factors – tenderness, juiciness, and flavor – to consumer overall eating experience. Moreover, most of the samples in the dataset included the USDA marbling score as well as the percentage of intramuscular fat. Because of this, the contribution of marbling and fat percentage to each palatability trait and overall eating experience was also evaluated.

In order to accomplish these objectives, the raw data from all studies were compiled as a single dataset. The average sensory score for each palatability trait was determined for each sample by averaging across the individual consumer ratings for the sample. A multivariate regression model was constructed using the sample means to determine the relative contribution of tenderness, juiciness, and flavor to consumer overall liking scores. The odds and relative risk of an unacceptable overall eating experience were determined based on the acceptability of the three individual sensory traits. Moreover, the percentage of samples from each quality grade that were identified as acceptable for each trait were determined and analyzed using a binomial model. Lastly, simple linear regression models were calculated to quantify the contribution of intramuscular fat percentage to consumer sensory ratings and logistic regression models were determined to estimate the probability of sensory trait acceptance based on intramuscular fat content.

Table 1. Descriptions of studies used in analyses

Project	Treatments Used	Muscles	Number of Consumers	Number of Samples
O'Quinn et al., 2012	Prime, High Choice, Low Choice, Select, Standard, Wagyu	*Longissimus dorsi*	120	72
Hunt et al., 2014	Top Choice, Select	*Longissimus dorsi* *Gluteus medius* *Semimembranosus* *Serratus ventralis*	120	108
Corbin et al., 2015	Prime, High Choice, Low Choice, Select, Standard, Wagyu, Grass-fed	*Longissimus dorsi*	120	64
Legako et al., 2015	Prime, High Choice, Low Choice, Select, Standard	*Longissimus dorsi* *Psoas major* *Gluteus medius* *Semimembranosus*	278	80
Cashman, 2015	Prime, Top Choice, Low Choice, Select, Standard; Young and Grain-finished Mature	*Longissimus dorsi*	120	150
Gredell, 2015	Select, Standard; Young, Grain-finished Mature, and Forage-finished Mature	*Longissimus dorsi*	120	90
Lucherk et al., 2016	Prime, Top Choice, Low Choice, Select, Standard, Enhanced Select	*Longissimus dorsi*	252	252
Wilfong et al., 2016	Prime, Top Choice, Low Choice, Select, Select Angus	*Longissimus dorsi*	112	80
Ron, 2016	Top Choice, Select, Grass-finished	*Longissimus dorsi*	240	240
McKillip, 2016	Prime, Low Choice, Low Select, Enhanced Prime, Enhanced Low Choice, Enhanced Select	*Longissimus dorsi*	252	252
Vierck, 2017	Top Choice, Low Choice, Select	*Longissimus dorsi*	104	117
Total			**1,838**	**1,505**

Results and Discussion

Modeling Beef Palatability

In order to develop a model for overall beef eating satisfaction, a multivariate regression analysis was used. Sample means from all 11 studies were included in the regression analysis to account for and include a large amount of variation in eating quality associated with the various treatments (muscle, degree of doneness, marbling level, animal diet, etc.). For this analysis, sample overall liking scores were used as the dependent variable and consumer tenderness, juiciness, and flavor liking scores as well as their interactions were used as explanatory variables. A step-wise selection procedure was used for inclusion of variables in the model. All variables that entered the model were significant ($P < 0.05$) and had to remain significant ($P < 0.05$) to be included in the final in the model. Additionally, the intercept was highly non-significant ($P > 0.70$) and was therefore excluded from the model. The final palatability model determined was:

$$\text{Consumer overall liking} = (0.42 \times \text{tenderness}) + (0.07 \times \text{juiciness}) + (0.48 \times \text{flavor})$$

This model accounted for greater than 99% of the variation ($R^2 > 0.99$) in consumer overall liking scores. This provides clear evidence that the linear combination of tenderness, juiciness, and flavor accounts for practically all of the variation in overall consumer eating satisfaction. The traits of tenderness, juiciness, and flavor have long been considered the most important palatability traits affecting beef eating quality. Some authors have also considered the impact of other factors such as texture, mouthfeel, appearance, and odor (Smith and Carpenter, 1974; Watson et al., 2008a). Results of the current study would indicate that though other factors may play a role in the perception of beef palatability, the contribution of these factors are likely also accounted for by measures of tenderness, juiciness, and flavor.

It is also noteworthy that the interaction terms among the three traits never entered the model, as they were non-significant ($P > 0.05$). This indicates that the effects of tenderness, juiciness, and flavor on overall eating satisfaction are not dependent upon the level of the other traits. It was hypothesized that the interaction of the traits might provide some synergy (ie. when all traits were at a certain positive level, the impact on overall eating quality would be greater than the sum; and vice versa for negative trait evaluations). However, no such interaction was found in this analysis.

When evaluating the contribution of each trait to overall eating quality, the equation indicates flavor contributes the most (49.4%), followed by tenderness (43.4%), and juiciness (7.4%). Additionally, changes in tenderness and flavor on overall eating quality are very close to equal, with a 1 unit change in flavor rating corresponding to a 1.1 unit change in tenderness. However, much larger changes in juiciness are required to equal changes in the other two traits. A change in juiciness of 5.9 units is needed to equal a 1 unit change in tenderness; and a 6.7 unit change is needed to equal a 1 unit change in flavor.

Many studies have asked consumers which palatability trait is the most important when consuming beef. Consumers from two such studies conducted in the mid-90's reported the majority of consumers (50-51%) indicated tenderness was most important, followed by flavor (39-40%), and the fewest (10%) stating juiciness (Miller et al., 1995b; Huffman et al., 1996). More recent studies have indicated a shift in these percentages, with the majority of today's consumers indicating flavor (49-50%) as the most important trait, with fewer consumers (36-40%) now identifying tenderness as most import (McKillip, 2016; Wilfong et al., 2016). However, the percentage of consumers who identify juiciness as most important has remained relatively constant, at close to 10% (McKillip, 2016; Wilfong et al., 2016). This shift in consumer emphasis away from tenderness and to beef flavor is reflected in the relative contribution of each trait in the determined regression model.

Other authors have reported regression models including the three palatability traits accounted for only 79% of the variation in overall palatability score, with flavor alone accounting for the most variation (67%) (Huffman et al., 1996). However, in that study the authors used 8-point hedonic scales as opposed to the line-scales used in the current studies, perhaps explaining some of the observed difference. Taking a different approach, Platter et al. (2003) modeled the effect of tenderness, juiciness, and flavor on overall sample acceptability (yes/no) as opposed to overall palatability score. In that study, the authors reported logistic regression equations for each trait alone explained over 50% of the variation in overall acceptability and the three variable model explained 62% of the total variation (Platter et al., 2003).

To date, the most extensive modeling of beef palatability as it relates to tenderness, juiciness, and flavor is the Meat Standards Australia (MSA) grading system. The MSA grading system differs from the U.S. system in many ways. One of the primary differences is the MSA grading system identifies and grades beef cuts (steaks, roasts, stew meat, stir-frys, etc.) based on predicted eating quality as opposed to carcasses, as is done in the U.S. (Polkinghorne et al., 2008). Cuts are assigned to one of four quality categories – premium quality (5 star), better than everyday quality (4 star), good everyday quality (3 star), and unsatisfactory (Watson et al., 2008a; Watson et al., 2008b). This is done through the calculation of a composited estimate of the eating quality (MQ4) based on an equation considering a variety of animal production and meat processing inputs (Watson et al., 2008b).

At the heart of this grading system is an ever-growing consumer database that has grown in consumer observations and sample numbers since it was first started in the late 1990s. These consumer observations provided the modeling information needed for the development of the MQ4 score. MQ4, as an estimate of composited eating quality, is calculated by the equation: $MQ4 = (0.4 \times \text{tenderness}) + (0.1 \times \text{juiciness}) + (0.2 \times \text{flavor}) + (0.3 \times \text{overall palatability})$ (Watson et al., 2008a). In this way, the MSA model weights beef eating quality as 40% tenderness, 30% overall palatability, 20% flavor, and 10% juiciness. A primary difference between the MSA palatability model and the calculated model in this report is the inclusion of overall palatability score as an independent explanatory variable in the MSA model as opposed to the dependent response variable as was done in this report. The largest difference between the two models is in the influence of flavor. In the model in this report, flavor was the largest contributor to overall eating quality, however in the MSA model, flavor is outweighed by both tenderness and overall palatability score. Nevertheless, the MSA model provides another indication of the relative contribution of tenderness, juiciness, and flavor to overall beef eating quality.

The palatability model determined for this report reflects the observed emphasis placed on beef flavor by today's beef consumers. A greater percentage of consumers have self-reported the importance of flavor in recent years, and the model indicates that this emphasis is reflected in their beef eating experiences. Tenderness, however, remains the second largest driver of overall eating quality, with a large portion of the beef eating experience dependent upon tenderness ratings. As the beef industry continues to change over the next decade, and with recent industry focus on beef flavor improvement, this palatability model should be reevaluated at regular intervals (every 5 or 10 years) to monitor the impact of industry changes impacting flavor, tenderness, and juiciness and their relative contribution to consumer eating satisfaction.

Odds of Overall Palatability Failure

When evaluating the contribution of tenderness, juiciness, and flavor to overall eating quality, it is important to determine the relative risk of a product failing overall due to the failure of one or more of the specific palatability traits. Throughout all of the included studies, yes/no acceptability questions were asked for the each of the traits, allowing the consumers to make a definitive assessment of whether or not the sample met their expectations for that trait. Table 2 provides the estimates for the likelihood of overall failure based the failure/acceptance of the other traits.

Odds ratios represent the relative increase in the odds of an event occurring (overall palatability failing) due to another event (unacceptable rating for tenderness, juiciness, or flavor). For example, in Table 2, the odds of overall palatability failing when tenderness is acceptable is 1 in 10 (10% chance), whereas the odds of overall palatability failing when tenderness is unacceptable is 2.2 to 1 (69% chance). Therefore the odds ratio is 20.8 (odds when tenderness is unacceptable / odds when tenderness is acceptable). So the odds of overall palatability failing when tenderness is unacceptable is 20.8 times higher than when tenderness is acceptable. The relative risk is the increased risk of an event occurring (overall unacceptable) due to another event (unacceptable tenderness). Thus, the likelihood of unacceptable overall palatability is 7.2 times higher when tenderness is unacceptable.

Table 2. Odds of an unacceptable eating experience based on tenderness, juiciness, and flavor acceptability

Palatability Trait	Odds when trait is acceptable[1]	Odds when trait is unacceptable[2]	Odds Ratio[3]	Relative Risk[4]
Tenderness	1 in 10	2.2 to 1	20.8	7.2
Juiciness	1 in 9	1.9 to 1	17.1	6.5
Flavor	1 in 15	3.3 to 1	49.0	12.3
Tenderness and Juiciness	1 in 15	6.3 to 1	92.0	13.5
Tenderness and Flavor	1 in 50	10.3 to 1	516.5	46.8
Juiciness and Flavor	1 in 35	8.3 to 1	293.7	32.4
Tenderness, Juiciness, and Flavor	1 in 93	21.5 to 1	1989.1	89.5

[1]Odds of overall eating experience failing when individual palatability trait is rated acceptable
[2]Odds of overall eating experience failing when individual palatability trait is rated unacceptable
[3]Relative increase in odds of unacceptable eating experience when trait is rated unacceptable (ie. Odds of failure are X times greater than when trait is acceptable)
[4]Increased risk of unacceptable eating experience when trait is unacceptable (ie. Overall unacceptable rating is X times more likely than when trait is acceptable)

With respect to flavor, only 1 in 15 (6.7% chance) steaks fail for overall palatability when flavor is also acceptable; however this increases to 3.3 to 1 (76% chance) when flavor is unacceptable. The odds of overall palatability failing when flavor is unacceptable are 49 times higher than when flavor is acceptable, and overall palatability failure is 12.3 times more likely due to unacceptable flavor.

For juiciness, 1 in every 9 steaks (11% chance) are unacceptable overall when juiciness is acceptable compared to close to 2 out of every 3 (66% chance) when juiciness is unacceptable. This indicates overall palatability is 6.5 times more likely to fail when juiciness is unacceptable, with the odds of failure 17.1 times greater due to juiciness failure. Though juiciness contributes only 10% to overall palatability, these results indicate the large impact that even juiciness failing to meet consumer expectations can have on overall palatability.

When more than one palatability trait fails, the odds of overall palatability failure increase dramatically. Most notably, when tenderness and flavor are both unacceptable, the odds of overall palatability failing are 516.5 times greater than when both traits are acceptable, with overall palatability more than 46 times more likely to fail when both traits are unacceptable. When juiciness fails in combination with tenderness or flavor, the odds of overall palatability failure are increased 92 and 294 times, respectively. Lastly, when all three traits are acceptable, only 1 in every 93 steaks (~1% chance) are unacceptable overall. However, when all three traits fail, the odds of failure increase almost 2,000 times to more than a 95% chance and the likelihood of overall failure is 89.5 times more likely.

These results indicate the significant consequences to overall beef palatability if one or more of the individual palatability traits are viewed as unacceptable by consumers. Though the regression analysis in the previous section provided insight to the relative contribution of each of these traits to overall eating quality, results presented in Table 2 demonstrate the importance of assuring that all three traits are at an acceptable level. Efforts to improve beef palatability focused on only a single trait should ensure that improvements in the single area are not at the detriment of the other two. The odds of beef failing to meet a consumer's overall eating expectations are increased significantly if even just one of the three individual traits are unacceptable.

Impact of Marbling and Intramuscular Fat Level

Many of the studies used in this data set included differences in USDA quality grade and its effect on palatability. Because of this, the data offered an opportunity to analyze and evaluate the contribution of marbling level and intramuscular fat content to beef eating quality. Numerous authors have previously evaluated this relationship, however, this set of data was restricted to only consumer panelists and therefore offered the opportunity to gain additional insight into the impact of marbling on consumer sensory perceptions. For these analyses the data was restricted to only steaks from the *longissimus dorsi* that were from young (A maturity) grain-finished cattle that were cooked to a medium (71°C) degree of doneness. Additionally, samples that had been enhanced with moisture solutions were also excluded from these analyses.

The percentage of samples from each quality grade that were rated as acceptable from the yes/no acceptability questions for each of the palatability traits are presented in Table 3. The percentage increased for tenderness (Prime > Premium Choice = Low Choice > Select = Standard), juiciness (Prime > Premium Choice = Low Choice > Select > Standard), flavor (Prime > Low Choice > Select = Standard) and overall palatability (Prime > Premium Choice > Low Choice > Select = Standard) as quality grade increased.

Table 3. Percentage of grain-finished strip loin steaks of various USDA quality grades cooked to a medium degree of doneness rated as acceptable by consumers

USDA Quality Grade	Tenderness	Juiciness	Flavor	Overall Liking
Prime	95.14[a]	92.42[a]	88.11[a]	91.37[a]
Premium Choice	86.61[b]	84.97[b]	85.44[ab]	86.83[b]
Low Choice	86.31[b]	83.33[b]	83.83[b]	83.08[c]
Select	77.30[c]	75.96[c]	75.38[c]	74.75[d]
Standard	74.53[c]	67.99[d]	72.29[c]	72.04[d]
SEM	1.81	1.94	1.86	1.86
P-Value	< 0.01	< 0.01	< 0.01	< 0.01

[abcd]Means in the same column lacking a common superscript differ ($P < 0.05$)

These results indicate that USDA quality grade effectively sorts steaks based upon palatability trait acceptability, with higher USDA quality grades having a higher percentage of steaks rated acceptable for each trait than lower grades. USDA Prime had more than 91% of samples rated acceptable for all traits other than flavor, representing a greater percentage than all lower grading beef. Conversely, almost 25% of Select beef failed to meet consumer expectations for all palatability traits, and had a similar percentage of samples rated unacceptable for all traits, other than flavor, as Standard. Currently, close to 20% of cattle nation-wide grade USDA Select

(USDA, 2016b). Taken together, this represents a large challenge for the U.S. beef industry. With such a large portion of lower grading (≤ Select) product failing to meet consumer eating expectations combined with the high percentage of carcasses currently in these grades, this represents a significant amount of beef product that will ultimately fail to meet consumer eating expectations. Moreover, the data presented in Table 3 included only strip steaks cooked to medium. The failure rate for Select beef is likely much higher considering the proportion of consumers who cook steaks to greater than medium (Reicks et al., 2011) and the negative impact of increased degree of doneness on beef palatability. The study by Lucherk et al. (2016) reported Select and Standard steaks cooked to well-done were rated unacceptable overall 46 and 50% of the time, respectively. In that study, only consumers who preferred well-done evaluated the well-done samples. There is the potential that this number could be much higher for consumers who prefer lower degrees of doneness and mistakenly overcook steaks at home or are served an overcooked steak at foodservice. Additionally, the failure rate for many of the tougher muscles in the carcass that are traditionally cooked via dry heat methods from Select may be much higher as well.

It is also interesting to note that Premium Choice (upper 2/3 of Choice grade) had a greater portion of samples rated acceptable overall than Low Choice, however a similar percentage of samples rated acceptable for each palatability trait. This advantage in overall palatability and demand by consumers is reflected in the premiums garnered by the wholesale cut prices of this category over commodity Choice products (USDA, 2016a).

These results differ from previous authors who have evaluated the probability of an unsatisfactory eating experience based on quality grade. A study by Smith et al. (2008) compiled results from 14 previous works and determined the probability of an unsatisfactory eating experience for Prime to be 1 in 33 (3%), Premium Choice to be 1 in 10 (10%), Low Choice to be 1 in 6 (16%), Select to be 1 in 4 (25%), and Standard to be 1 in 2 (50%). Additionally a more recent report by Tatum (2015) composited results from 5 more recent studies and reported the odds of failure to be 1 in 33.6, 1 in 13.8, 1 in 5.4, 1 in 2.9, and 1 in 2.2 for Prime, Premium Choice, Low Choice, Select, and Standard, respectively. Results from the current study indicate that the odds of Prime steaks failing to produce an acceptable eating experience are actually much higher (1 in 10.6) than reported by these previous authors. Moreover, the probability of Premium Choice producing an unacceptable eating experience is also higher (1 in 6.6) than previously reported. Estimates for the failure rate in the current analysis were similar to those reported by Tatum (2015) for Low Choice (1 in 4.9 vs 1 in 5.4); however the current study indicated that the probability of a satisfactory eating experience in the lower to grades was actually higher than the values reported by Tatum (2015); 75% vs 66% for Select and 72% vs 55% for Standard.

The observed differences between the current work and that of Smith et al. (2008) and Tatum (2015) is likely the result of the differences in study types used for the analyses. Both

Smith et al. (2008) and Tatum (2015) included studies in their analyses that were comprised of trained sensory panelists. Trained panels are designed in order to evaluate sensory traits as objectively as possible. Additionally, trained sensory panelists must complete a training or orientation procedure in order to insure that the panelists are assessing all traits similarly, and that the amount of variation among samples as assessed across the panel is minimal. Because of this, the data from trained sensory panelists should not be interpreted the same as results from consumer panelists who assess samples based on their own individual biases and interpretations. Trained panelists are also much more discriminating than consumer panelists, allowing for greater separation among samples of different treatments and quality grades. Additionally, many of the works used by these authors did not contain yes/no acceptability questions, leaving the authors to have to make a judgement based on the sensory score on the rating scale as to whether or not the sensory panelist would have considered the overall eating experience satisfactory (acceptable).

These differences in the types of studies used and the method for determination of negative/unacceptable eating experience are likely responsible for the observed differences. It appears the use of the trained panel data in these analyses skewed the likelihood of negative eating experiences for the highest marbled (Prime and Premium Choice) and the lowest marbled (Select and Standard) grades. The previous reports underestimated the likelihood of product unacceptability for the high marbled products and overestimated the likelihood in the low marbled products. The data presented in the current report is reflective of the percentage of samples from these quality grades that were rated acceptable by consumers (yes/no) and provide one of the best estimates of the actual failure rate for these grades as consumed by beef end users and consumers.

Simple linear regressions were also performed to assess the impact of marbling level and fat on each of the palatability traits (Table 4). Marbling content was related ($P < 0.05$) to all four palatability traits, but explained only 15, 16, 14, and 16% of the variation in sensory panel tenderness, juiciness, flavor, and overall liking ratings, respectively. Differences in personnel assessing marbling level to the 10^{th} of a marbling score as well as the high level of variability among consumer panelists makes modeling the relationship difficult, especially across the number of studies used within this analysis. The percentage of intramuscular fat however is a more objective measure of marbling content. Regression equations for each of the palatability traits utilizing intramuscular fat content accounted for a slightly greater amount of variation in consumer palatability scores than marbling content, with intramuscular fat accounting for 17, 21, 17, and 17% of the variation in tenderness, juiciness, flavor, and overall palatability, respectively (Table 4).

The slope for the relationship between juiciness and intramuscular fat content was the greatest, indicating that changes in fat content would result in larger increases in juiciness scores than the other traits (Fig. 1). The regressions revealed that for all traits an increase of close to 3%

intramuscular fat would be needed to increase the palatability rating by 5 units. Thompson (2004) reported a curvilinear response between fat percentage and consumer palatability scores within data from the MSA dataset. He reported changes of about 2% intramuscular fat needed for a 5 point increase (on similar 100 mm scales) in palatability ratings, with the ratings peaking at 15.5, 17.3, 13.8, and 14.1% intramuscular fat for tenderness, juiciness, flavor, and overall liking, respectively. However, the author did not provide an estimate of the percentage of variation accounted for by the models (R^2). In the current report, an evaluation of non-linearity was assessed, but the curvilinear effect was non-significant and did not enter the model, indicating that a similar curvilinear response with palatability traits peaking at a given intramuscular fat percentage was not present in the current dataset.

Table 4. Equations for linear regressions of marbling and intramuscular fat percentage and consumer palatability ratings and logistic equations for the probability of acceptable palatability ratings based on fat percentage

	Intercept	Regression Coefficient	Adjusted R^2	*P* - value
Marbling Score				
Tenderness	44.82	0.03	0.15	< 0.01
Juiciness	44.17	0.03	0.16	< 0.01
Flavor Liking	46.18	0.03	0.14	< 0.01
Overall Liking	43.79	0.03	0.16	< 0.01
Fat Percentage				
Tenderness	51.82	1.60	0.17	< 0.01
Juiciness	49.35	1.77	0.21	< 0.01
Flavor Liking	50.49	1.47	0.17	< 0.01
Overall Liking	50.28	1.44	0.17	< 0.01
Fat % - Probability of Acceptance				
Tenderness	0.80	0.15	0.09	< 0.01
Juiciness	0.68	0.14	0.08	< 0.01
Flavor	0.86	0.10	0.05	< 0.01
Overall Liking	0.70	0.14	0.09	< 0.01

Logistic regression allows for the prediction of the probability of a binomial event (yes/no) occurring using a continuous variable as an independent predictive variable. Logistic regression equations were calculated to determine the probability of a palatability trait being rated acceptable based on intramuscular fat percentage (Table 4; Fig. 2). Similar to the linear regressions, models using intramuscular fat percentage to predict the probability of a sensory trait being rated acceptable were significant ($P < 0.05$), but accounted for only a small percentage (< 10%) of the variation in trait acceptability. Nevertheless, the model indicated that 6.2, 7.7, 9.0, and 7.6% intramuscular fat would be required for an 85% chance of tenderness, juiciness, flavor, and overall liking being rated acceptable, respectively. This corresponds to Premium Choice (upper 2/3) for tenderness, juiciness, and overall liking and Prime for flavor (Savell et al., 1986). The probability increases to 90% with intramuscular fat percentages of 9.3, 11.0, 13.7, and 11.0% for tenderness, juiciness, flavor, and overall liking, respectively. This indicates that at least a Prime quality grade is required for a 90% probability of each palatability trait to be rated acceptable, which is consistent with results reported in Table 3. Platter et al. (2003) also used logistic regression to predict overall beef sample acceptance based on marbling level. Those authors, similar to the current study, found marbling level represented only a small percentage (5%) of the variation in the probability of overall sample acceptance.

Using objective measures such as fat percentage to predict consumer sensory scores often produce significant relationships that account for only a small amount of variation (Dikeman, 1987; Dikeman, 1996). Previous authors have reported marbling score accounted for only 27, 20, 26, and 33% of the variation in trained sensory panel flavor, juiciness, tenderness, and overall palatability scores (Smith et al., 1984). Warner-Bratzler shear force values, a global industry standard, have been shown to account for only 36-73% of the variation in trained sensory panel tenderness scores (Shackelford et al., 1995; Caine et al., 2003) and 30% of the variation in consumer panel tenderness ratings (McKillip, 2016). The significant, but weak, predictive ability of both fat percentage and marbling score observed within the current dataset underscores the difficulty in using such objective measures alone to predict eating quality.

Fig. 1 - Linear Regression of Palatability Ratings and Fat Percentage

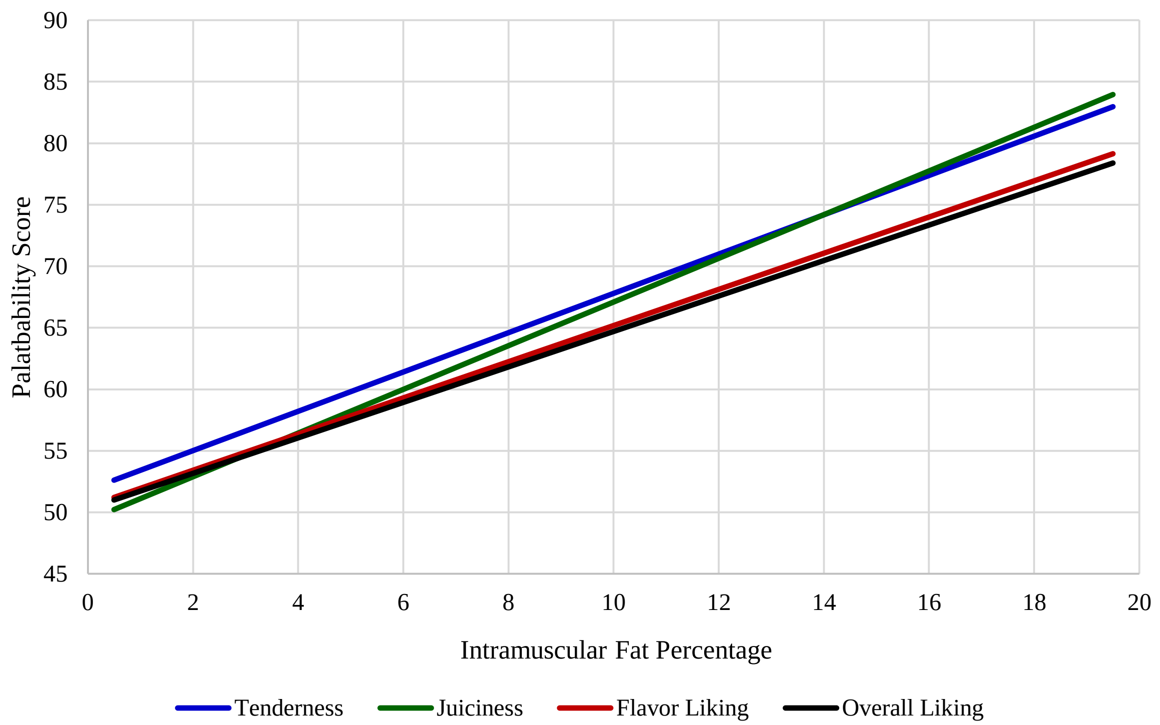
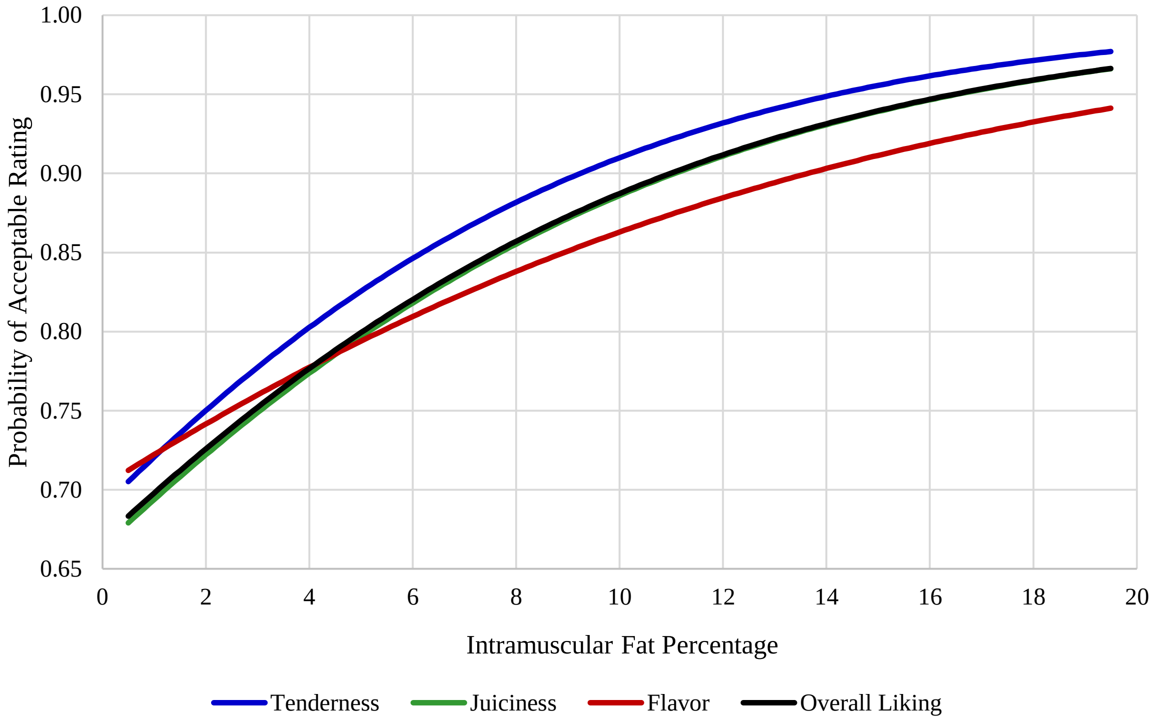


Fig. 2 - Probability of Acceptable Palatability Raiting based on Intramusclular Fat Percentage



Conclusions

Results of this study provide a model for estimation of overall palatability based on tenderness, juiciness, and flavor. The model allows for a comparison of the relative contribution of each of these traits to overall eating quality. Moreover, estimates related to the relative risk of overall palatability failure when one or more of the traits of tenderness, juiciness, and flavor are unacceptable were determined. The calculated risk and odds ratios provide evidence of the large impact that the failure of a single palatability trait can have on overall beef palatability. Though marbling plays a large role in beef palatability, using marbling or fat level as a predictor of eating quality remains a challenge due primarily to the large number of factors aside from marbling impacting beef eating quality.

Literature Cited

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. Gardner, 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.

Caine, W. R., J. L. Aalhus, D. R. Best, M. E. R. Dugan, and L. E. Jeremiah. 2003. Relationship of texture profile analysis and Warner-Bratzler shear force with sensory characteristics of beef rib steaks. Meat Sci. 64:333-339.

Cashman, D. A. 2015. Evaluation of beef strip loin steaks of varying marbling scores and maturity levels fed a high energy corn-based concentrate diet prior to harvest. Master's Thesis, Texas Tech University, Lubbock, TX.

Corbin, C. H., T. G. O'Quinn, A. J. Garmyn, J. F. Legako, M. R. Hunt, T. T. N. Dinh, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2015. Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments. Meat Sci. 100:24-31. doi:10.1016/j.meatsci.2014.09.009

Dikeman, M. E. 1987. Fat reduction in animals and the effects on palatability and consumer acceptance of meat products. In: Reciprocal Meat Conference. p 93-103.

Dikeman, M. E. 1996. The relationship of animal leanness to meat tenderness. In: Reciprocal Meat Conference Proceedings. p 87-101.

Egan, A. F., D. M. Ferguson, and J. M. Thompson. 2001. Consumer sensory requirements for beef and their implications for the Australian beef industry. Aust. J. Exp. Agric. 41:855-859. doi:10.1071/EA00065

Gredell, D. A. 2015. Evaluation of beef strip loin steaks from young beef, mature unfed cows, and cull-cows fed a high energy corn-based concentrate diet prior to harvest. Master's Thesis, Texas Tech University, Lubbock, TX.

Guelker, M. R., A. N. Haneklaus, J. C. Brooks, C. C. Carr, R. J. Delmore, D. B. Griffin, D. S. Hale, K. B. Harris, G. G. Mafi, D. D. Johnson, C. L. Lorenzen, R. J. Maddock, J. N. Martin, R. K. Miller, C. R. Raines, D. L. VanOverbeke, L. L. Vedral, B. E. Wasser, and J. W. Savell. 2013. National Beef Tenderness Survey–2010: Warner-Bratzler shear force values and sensory panel ratings for beef steaks from United States retail and food service establishments. J. Anim. Sci. 91:1005-1014. doi:10.2527/jas.2012-5785

Huffman, K. L., M. F. Miller, L. C. Hoover, C. K. Wu, H. C. Brittin, and C. B. Ramsey. 1996. Effect of beef tenderness on consumer satisfaction with steaks consumed in the home and restaurant. J. Anim. Sci. 74:91-97.

Killinger, K. M., C. R. Calkins, W. J. Umberger, D. M. Feuz, and K. M. Eskridge. 2004. Consumer sensory acceptance and value for beef steaks of similar tenderness, but differing in marbling level. J. Anim. Sci. 82:3294-3301.

Legako, J. F., J. C. Brooks, T. G. O'Quinn, T. D. J. Hagan, R. Polkinghorne, L. J. Farmer, and M. F. Miller. 2015. Consumer palatability scores and volatile beef flavor compounds of five USDA quality grades and four muscles. Meat Sci. 100:291-300. doi:10.1016/j.meatsci.2014.10.026

Lucherk, L. W., T. G. O'Quinn, J. F. Legako, R. J. Rathmann, J. C. Brooks, and M. F. Miller. 2016. Consumer and trained panel evaluation of beef strip steaks of varying marbling and enhancement levels cooked to three degrees of doneness. Meat Sci. 122:145-154. doi:10.1016/j.meatsci.2016.08.005

Lyford, C., J. Thompson, R. Polkinghorne, M. Miller, T. Nishimura, K. Neath, P. Allen, and E. Belasco. 2010. Is willingness to pay (WTP) for beef quality grades affected by consumer demographics and meat consumption preferences. Australasian Agribusiness Review 18:1-17.

McKenna, D. R., D. L. Roebert, P. K. Bates, T. B. Schmidt, D. S. Hale, D. B. Griffin, J. W. Savell, J. C. Brooks, J. B. Morgan, T. H. Montgomery, K. E. Belk, and G. C. Smith.

2002. National Beef Quality Audit-2000: survey of targeted cattle and carcass characteristics related to quality, quantity, and value of fed steers and heifers. J. Anim. Sci. 80:1212-1222.
McKillip, K. V. 2016. Determination of the repeatability and accuracy of the pressed juice percentage (PJP) method at sorting beef strip loin steaks into categories of known juiciness. Master's Thesis, Kansas State University, Manhattan, KS.
Miller, M. F., L. C. Hoover, K. D. Cook, A. L. Guerra, K. L. Huffman, K. S. Tinney, C. B. Ramsey, H. C. Brittin, and L. M. Huffman. 1995a. Consumer acceptability of beef steak tenderness in the home and restaurant. J. Food Sci. 60:963-965.
Miller, M. F., K. L. Huffman, S. Y. Gilbert, L. L. Hamman, and C. B. Ramsey. 1995b. Retail consumer acceptance of beef tenderized with calcium chloride. J. Anim. Sci. 73:2308-2314.
O'Quinn, T. G., J. C. Brooks, R. J. Polkinghorne, A. J. Garmyn, B. J. Johnson, J. D. Starkey, R. J. Rathmann, and M. F. Miller. 2012. Consumer assessment of beef strip loin steaks of varying fat levels. J. Anim. Sci. 90:626-634. doi:10.2527/jas.2011-4282
Platter, W. J., J. D. Tatum, K. E. Belk, P. L. Chapman, J. A. Scanga, and G. C. Smith. 2003. Relationships of consumer sensory ratings, marbling score, and shear force value to consumer acceptance of beef strip loin steaks. J. Anim. Sci. 81:2741-2750.
Polkinghorne, R., J. M. Thompson, R. Watson, A. Gee, and M. Porter. 2008. Evolution of the Meat Standards Australia (MSA) beef grading system. Aust. J. Exp. Agric. 48:1351-1359. doi:10.1071/EA07177
Reicks, A. L., J. C. Brooks, A. J. Garmyn, L. D. Thompson, C. L. Lyford, and M. F. Miller. 2011. Demographics and beef preferences affect consumer motivation for purchasing fresh beef steaks and roasts. Meat Sci. 87:403-411.
Ron, O. 2016. Influence of brand recognition on consumer perception of beef palatability of top loin steaks – *In Preparation*. Master's Thesis, Texas Tech University, Lubbock, TX.
Savell, J. W., R. E. Branson, H. R. Cross, D. M. Stiffler, J. W. Wise, D. B. Griffin, and G. C. Smith. 1987. National consumer retail beef study: palatability evaluations of beef loin steaks that differed in marbling. J. Food Sci. 52:517-519.
Savell, J. W., H. R. Cross, and G. C. Smith. 1986. Percentage ether extractable fat and moisture content of beef longissimus muscle as related to USDA marbling score. J. Food Sci. 51:838-839. doi:10.1111/j.1365-2621.1986.tb13946.x
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., T. L. Wheeler, and M. Koohmaraie. 1995. Relationship between shear force and trained sensory panel tenderness ratings of 10 major muscles from Bos indicus and Bos taurus cattle. J. Anim. Sci. 73:3333-3340.
Shackelford, S. D., T. L. Wheeler, M. K. Meade, J. O. Reagan, B. L. Byrnes, and M. Koohmaraie. 2001. Consumer impressions of Tender Select beef. J. Anim. Sci. 79:2605-2614.
Smith, G. C., and Z. L. Carpenter. 1974. Eating quality of animal products and their fat content. Changing the fat content and composistion of animal products. p 124-137. National Academy Press, Washington, D.C.

Smith, G. C., Z. L. Carpenter, H. R. Cross, C. E. Murphey, H. C. Abraham, J. W. Savell, G. W. Davis, B. W. Berry, and F. C. Parrish Jr. 1984. Relationship of USDA marbling groups to palatability of cooked beef. J. Food Qual. 7:289-308.

Smith, G. C., J. W. Savell, R. P. Clayton, T. G. Field, D. B. Griffin, D. S. Hale, M. F. Miller, T. H. Montgomery, J. B. Morgan, and J. D. Tatum. 1992. Improving the consistency and competitiveness of beef. The Final Report of the National Beef Quality Audit—1991. National Cattlemen's Association, Englewood, CO:1-237.

Smith, G. C., J. D. Tatum, and K. E. Belk. 2008. International perspective: characterisation of United States Department of Agriculture and Meat Standards Australia systems for assessing beef quality. Aust. J. Exp. Agric. 48:1465-1480. doi:10.1071/EA08198

Tatum, J. D. 2015. Recent trends: beef quality, value and price. Certified Angus Beef, Wooster, OH.

Thompson, J. M. 2004. The effects of marbling on flavour and juiciness scores of cooked beef, after adjusting to a constant tenderness. Aust. J. Exp. Agric. 44:645-652. doi:10.1071/EA02171

USDA. 2016a. National daily boxed beef cutout and boxed beef cuts. USDA Market News, Des Moines, IA

USDA. 2016b. USDA national steer and heifer estimated grading percent report. USDA Market News, Des Moines, IA.

Vierck, K. R. 2017. Evaluation of the role of marbling texture in beef tenderness and juiciness perception - *In Preparation*. Master's Thesis, Kansas State University, Manhattan, KS.

Watson, R., A. Gee, R. Polkinghorne, and M. Porter. 2008a. Consumer assessment of eating quality – development of protocols for Meat Standards Australia (MSA) testing. Aust. J. Exp. Agric. 48:1360-1367. doi:10.1071/EA07176

Watson, R., R. Polkinghorne, and J. M. Thompson. 2008b. Development of the Meat Standards Australia (MSA) prediction model for beef palatability. Aust. J. Exp. Agric. 48:1368-1379. doi:10.1071/EA07184

Wilfong, A. K., K. V. McKillip, J. M. Gonzalez, T. A. Houser, J. A. Unruh, E. A. E. Boyle, and T. G. O'Quinn. 2016. The effect of branding on consumer palatability traits of beef strip loin steaks. J. Anim. Sci. doi:doi: 10.2527/jas.2016-0893