Is it time for Super Prime?

by

Chesney Alayna Effling

B.S., Kansas State University, 2024

A THESIS

submitted in partial fulfillment of the requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences & Industry
College of Agriculture

KANSAS STATE UNIVERSITY
Manhattan, Kansas

2025

Approved by:

Major Professor
Dr. Travis O'Quinn

Copyright

Abstract

USDA Prime carcass numbers have risen steadily over the past 25 years, but the grade remains undifferentiated in value-based marketing programs. As Prime availability grows, opportunities exist to capture added value by differentiating this grade, similar to the USDA Choice grade. Therefore, the objective of this study was to evaluate palatability characteristics of strip loin steaks from upper 2/3 Prime (Super Prime), Low Prime, Top Choice, and Low Choice across three degrees of doneness (DOD): Rare, Medium, and Well-Done. Steaks were designated for consumer evaluation, trained sensory evaluation, or objective measurements. There were no ($P > 0.05$) quality grade × DOD interactions for any consumer or trained panel-evaluated traits. Super Prime steaks were rated higher ($P < 0.05$) for all sensory traits evaluated by consumers and trained panelists compared to all other grades. Low Prime, Top Choice, and Low Choice did not differ ($P > 0.05$) for juiciness, flavor, or overall liking, although Low Prime was more tender ($P < 0.05$) than Low Choice. A higher percentage ($P < 0.05$) of Super Prime steaks were rated as acceptable for juiciness, flavor, and overall liking than all other quality grades. Rare steaks were juicier and more tender ($P < 0.05$) than Medium and Well-Done steaks, while Medium and Well-Done samples were similar ($P > 0.05$) for those traits. There was a quality grade × DOD interaction ($P < 0.05$) for objective tenderness and moisture measures. Across all DODs, Super Prime steaks were the lowest ($P < 0.05$) for WBSF. These results indicate that consumers preferred the eating quality of upper 2/3 Prime steaks over the other grades evaluated and supports the opportunity for a premium program within the Prime grade, offering the beef industry a valuable opportunity to capture added value from this highest grade within beef.

Key Words: beef, consumer USDA Prime, palatability, quality

Table of Contents

List of Figures

List of Tables

Acknowledgements

It only seems fitting that I am sitting to write this in my last Saturday practice as a meat judging coach at K-State. The last year and a half of my master's program has gone by in the blink of an eye, between coaching a meat judging team, conducting research, and still trying to be as involved with stuff at home, I have been more than busy. With that, there is a laundry list of people I have to thank for making all of this possible.

First and foremost, I wouldn't be in this spot without Dr. Travis O'Quinn. Travis, you have been a constant in my life for the last 5 years as I worked through my undergrad and master's, and I can't imagine going anywhere else for my Ph.D. Words cannot express I grateful I am for all you have taught me about judging, research, and life. I will cherish the time I have got to spend with you in the van and plant and the memories that have been made along the way. The yap sessions in the plant cafeteria and grad office rank up there as some of my favorite times.

To my "kids"- getting to coach the nine of you is one of the greatest honors of my life thus far. Seeing the look on your faces when something (finally) clicks or the excitement when you've done well on something brings me such joy. Outside of judging, the nine of you are some of my favorite humans I get to be around. It's funny how such different people can come together for this very weird thing we do and still get along so well and hold similar character traits. You are all such smart, funny, and kind individuals and I cannot wait to see all the amazing things each and every one you will do in life, and I will be your biggest fan cheering you on every step of the way. I have loved getting to be your "single mom who works too hard".

I would be remiss if I didn't thank my fellow graduate students that helped me complete this project. We have the best group of grad students that have brought me some of my closest friends that helped get me through the last year and a half. My name might technically be on this thesis, but none of it would have been possible without these people. Mason- thank you for being our go-to meat lab guy and teaching me how to do so many things in the lab. Sidney- thank you for always stepping out of your comfort zone to help on any/all O'Quinn research, you truly are one of the best human beings I've met. Greta- I am so happy Erin saved you from the north land and brought you to K-State, I can't image doing grad school without you. Lauren- I am so happy you came to MHK for your master's, and I can't thank you enough for all you did for my project, from product collection all the way to cooking a lot of steaks for trained panels, but most importantly thank you for your friendship. Katelynn- you are one of the kindest, most level-headed people I've met and I am so grateful to have a friend like you through undergrad and our master's. Sam- I could write a book about all the stories and memories you and I have made over the last four years and those we have yet to make but I'll leave it at this- I will always be grateful for that August day on Northfield and thank you for being the best friend I could ask for.

Lastly, the people who got me where I am today, my family. Anyone who knows me knows how close I am with my family. I always say that I have the most supportive, co-dependent, overbearing family you will ever meet, and I say that with all the love in my heart. Mom and Dad- you have instilled in me a love for agriculture that I can't imagine my life without. Although my path in life may look different than yours, you guys have supported me every step of the way and do whatever it takes to help me make my dreams come true. Cagney- my big sister, my first phone call when I need help, my first best friend. I will always be grateful for the year of college I got to spend with you, you and your group of friends showed me all there is to love about K-State and Manhattan, Kansas. You talk me off the ledge when I need it, tell me when I need to put my head on straight, but most of all you are the first one to help me

celebrate my wins in life. Kenidey- my baby sister, biggest cheerleader, the one that picks me up when I'm down. I never knew how much I would love to be a big sister but helping you accomplish your goals and supporting you in everything you do is one of my favorite things in life, and I am so proud of you. I am so happy you made the choice to transfer to K-state and we get to spend the next three years living in the same town. Thank you for knowing when life is getting to be too much for me and picking up the pieces.

Dedication

This thesis is dedicated to my family. Mom, Dad, Cagney, and Kenidey- thank you for supporting me in everything I do in life and being with me every step of the way.

Chapter 1 - Review of Literature

From Grade to Plate: Evaluating Marbling, Palatability, and Economic Trends in U.S. Beef

Introduction

The United States beef industry continually strives to enhance the eating quality and value of beef products, focusing on traits consumers prioritize such as tenderness, juiciness, and flavor. Central to this pursuit is the United States Department of Agriculture (**USDA**) beef grading system, which separates carcasses based on marbling and physiological maturity to predict eating quality (USDA, 2017). In recent decades, consumer preference for marbled, high-quality beef has grown, leading to an increase in carcasses grading USDA Prime and USDA Choice (Umberger et al., 2000; USDA-AMS, 2024). Correspondingly, economic incentives, reflected in cutout values and branded beef programs, have reinforced the industry's commitment to marbling enhancement (Williams, 2006; USDA-AMS, 2025a). Outside of marbling content, there are a number of factors that can contribute to the eating experience of beef for consumers, such as degree of doneness. Therefore, this literature review aims to explore the multifaceted relationship between USDA quality grades, carcass marbling score, degree of doneness, and their combined impacts on consumer palatability and market value, providing context for current trends and opportunities within the U.S. beef sector.

The impact of marbling on eating quality

The USDA established the final rendition for the standards used in the U.S. beef grading system in 1997. However, the initial proposal for the grades occurred in 1917, with many amendments and improvements taking place over the next 80 years (USDA, 2017). The grading system was set up to separate carcasses into categories based on their expected eating experience, known as quality grade (USDA, 2017). In order to determine the grade categories in which carcasses classify, carcasses are evaluated for the physiological maturity of the carcass and the intramuscular fat (marbling) between the 12^{th} and 13^{th} rib. The quality grades that a steer or heifer less than 30 months of age are eligible for include USDA Prime, Choice, Select, and Standard. In the early 1960's, it was established that carcasses also needed to be separated by their expected boneless closely trimmed retail cuts, known as yield grade (USDA, 2017). The factors used to determine yield grade include adjusted fat thickness between the 12^{th} and 13^{th} rib, percentage of kidney, pelvic, and heart fat, hot carcass weight, and ribeye area between the 12^{th} and 13^{th} rib.

The relationship between marbling and eating quality has been extensively researched over the last 50 years. Research in this area has most often explored palatability and the three traits that encompass it: tenderness, juiciness, and flavor. A foundational study on eating quality and fat content by Smith and Carpenter (1974) explored a number of different theories surrounding fat content and its impact on palatability traits. Most notably, they discuss different theories surrounding marbling's impact on tenderness. The major ideas put forward by Smith and Carpenter (1974) related to marbling and eating quality include the bite theory, the strain theory, and the lubrication theory. The bite theory indicates that increasing the fat content in a piece of meat replaces protein with lipid, and therefore lowers the bulk density (Smith and Carpenter, 1974). Ultimately, this is attributed to fat being less resistant to shear force with an increase in tenderness. The strain theory states that as fat is deposited in the connective tissue layers in muscle, connective tissue layers are therefore thinned and the toughness of meat is decreased (Smith and Carpenter, 1974). The lubrication theory says that intramuscular fats serve as a lubricant to the muscle fiber proteins and results in a more tender and juicy eating experience (Smith and Carpenter, 1974).

Numerous previous studies demonstrate the connection between increased USDA quality grade and increased eating experience (Tatum et al., 1980; Smith et al., 1985; O'Quinn et al., 2012; Emerson et al., 2013; Corbin et al., 2015a). A study by Tatum et al. (1980) involving quality grades from USDA High Choice to USDA Low Good noted a general increase in palatability sensory traits as marbling score increased, although those differences were not always statistically significant. Smith et al. (1985) found with higher USDA quality grades, there was an increase in sensory ratings by trained panelists in strip loin steaks. These results were coupled with a decrease in shear force values (Smith et al., 1985).

Thompson (2004) evaluated the relationship between consumer sensory scores and intramuscular fat percentage using data from over 3500 strip loin samples. Consumers evaluated samples for tenderness, juiciness, flavor liking, and overall liking at varying fat levels. The study found a curvilinear relationship between fat percentage and consumer ratings for tenderness, juiciness, flavor liking, and overall liking (Thompson, 2004). This indicates there is a potential plateau in consumer sensory scores at a fat content of 15 - 17% (Thompson, 2004). These authors found a high correlation between sensory scores, resulting in a confounding effect between traits. To minimize this, flavor and juiciness scores were adjusted for peak force. Even with this adjustment, there was still a curvilinear relationship between these two factors and fat percentage (Thompson, 2004). After the adjustment, the plateau occurred at 14% for flavor and 20% for juiciness (Thompson, 2004)

A study by O'Quinn et al. (2018) compiled data from more than 10 different consumer palatability studies to evaluate the contribution of tenderness, juiciness, and flavor to the overall eating experience of consumers. The results showed tenderness accounted for 43.4% of overall palatability, juiciness accounted for 49.4%, and flavor accounted for only 7.4% of overall palatability (O’Quinn et al., 2018). The study also looked at the percentage of samples for each quality grade that were acceptable for each palatability trait. While over 88% of USDA Prime samples were acceptable for each palatability trait, only 74.8-77.3% of USDA Select samples were rated acceptable for palatability traits (O’Quinn et al., 2018). Unlike Thompson (2004), O’Quinn et al. (2018) did not observe the same plateau in sensory scores at higher fat percentages.

O'Quinn et al. (2012) had consumers evaluate strip loin steaks with varying fat levels for tenderness, juiciness, flavor liking, and overall liking, and also aimed to explore the window of acceptability for fat content for consumers. The quality grades represented included USDA Prime, High Choice, Low Choice, Select and Standard, as well as Australian Wagyu and Australian grain finished (O'Quinn et al., 2012). For the U.S. quality grades, consumers found that with increased fat content, there was an increase in the rating of tenderness, juiciness, flavor liking, and overall liking (O'Quinn et al., 2012). However, when compared to the U.S. sourced beef, the Australian Wagyu beef was negatively impacted for flavor and overall liking by the increased fat content of the Wagyu cattle (O'Quinn et al., 2012).

A study by Emerson et al. (2013) aimed to quantify the relationship between instrumental marbling measurements used by the USDA and palatability traits and shear force. This study looked at 7 different marbling categories, including Traces, Slight, Small, Modest, Moderate, Slightly Abundant, and Moderately Abundant. With each increase in marbling degree, there was an increase in buttery/beef fat flavors found by the panelists, with moderately abundant being rated the highest for those traits (Emerson et al., 2013). In a similar pattern, with increased marbling level panelists found steaks to be more juicy, with moderately abundant steaks as the juiciest (Emerson et al., 2013). The study found the marbling score explained 61% of the variation in panel ratings for the overall sensory experience (Emerson et al., 2013). They also looked at the percentage of samples which received positive ratings for overall sensory experience. The results showed moderately abundant/slightly abundant had 98-99% positive ratings, moderate/modest had 80-90% positive ratings, small had 62% positive ratings, slight had 29% of positive ratings, and traces had 15% positive ratings (Emerson et al., 2013).

Corbin et al. (2015a) evaluated beef strip loin steaks of different quality grades that were exclusively considered tender on the Warner-Bratzler Shear Force (**WBSF**) scale. Despite all samples being considered tender, trained and consumer panelists still found differences in the sensory traits evaluated, including tenderness. Once again, generally as fat content increased in the U.S. quality grades, consumer sensory ratings also increased. However, much like in the O'Quinn et al. (2012) study, this study found the ultra-high fat content of the Australian Wagyu resulted in a decrease in the percentage of samples considered acceptable for overall liking when compared to USDA Prime steaks (Corbin et al., 2015a). Nyquist et al. (2018) had consumers evaluate USDA Prime, Choice, and Select cuts from the longissimus lumborum for palatability traits. Their study consistently found a stair-stepping effect for each of the palatability traits evaluated, with an increase in quality grade resulting in an increase in consumer ratings (Nyquist et al., 2018). Farmer (2022) had consumers evaluate Top Choice and USDA Select bone-in versus boneless ribeyes, strip loins, and tenderloins. Their consumers found, regardless of bone state or cut type, the Top Choice were more tender, more juicy, more flavorful, and were more acceptable overall (Farmer et al., 2022).

In a recent study by McKinzie et al. (2025), consumers evaluated strip loin steaks from 5 marbling degrees- slightly abundant and greater, moderate, modest, small, and slight- for tenderness, juiciness, flavor liking and intensity, overall liking, and the acceptability of these traits as well as their willingness to pay for those products. Overall, palatability ratings decreased with decreasing marbling degrees (McKinzie et al., 2025). For all sensory traits evaluated, slightly abundant and moderate steaks were rated similar, but slightly abundant steaks were more tender, juicy, and had a higher flavor and overall liking than modest steaks (McKinzie et al., 2025).

Impact of USDA Prime grade on eating quality in the longissimus muscle

As it has been established, there has been extensive research on the impact of USDA quality grade on the eating experience in beef steaks. Within this research, there is a vast body of work evaluating USDA Prime strip loin steaks in comparison to lower quality grades. Despite the vast research done in this space, there are mixed results on palatability ratings between these grades.

Often in these studies, there have been few differences between USDA Prime (Slightly Abundant and greater marbling score) and Top Choice (Modest and Moderate marbling score) steaks. Cashman (2015) evaluated strip loin steaks with Slightly Abundant and greater marbling, Modest and Moderate, Small, Slight, and Traces and Practically Devoid. This study found the Slightly Abundant steaks to be similar to the Modest and Moderate in young cattle for all sensory ratings and the percentage of samples considered acceptable for traits evaluated by consumers (Cashman, 2015). However, the same study's trained panelists rated USDA Prime steaks the highest for initial juiciness and sustained juiciness. Legako et al. (2015a) found no differences between USDA Prime and Top Choice steaks for any sensory traits evaluated by consumers. There was, however, a difference in the percentage of fat between the two treatments, with USDA Prime at 13.1% and Top Choice at 7.9% (Legako et al., 2015a).

Wilfong et al. (2016) conducted a study to determine the effect of branding on consumer palatability traits in strip loin steaks, where USDA Prime and Choice steaks were compared to steaks labeled as Certified Angus Beef (**CAB**). For each of the categories, the fat percentages were as follows: USDA Prime 8.9%, CAB 5.4%, and USDA Choice 3.7%, which all differed (Wilfong et al., 2016). Despite the statistical differences in fat content, the consumer palatability evaluation did not match. When consumers were not informed with a brand, USDA grade, or product type, USDA Prime only differed from CAB for juiciness, but differed from USDA Choice in all sensory traits evaluated (Wilfong et al., 2016). When consumers were given information on the product, USDA Prime steaks differed from CAB for juiciness and overall liking, and differed from USDA Choice in all sensory traits evaluated (Wilfong et al., 2016).

Corbin et al. (2015a) compared strip loin steaks of different fat levels, animal diets, and cattle types to see what consumer sensory scores would be when all samples were classified as tender based on WBSF values. In this study, USDA Prime (14.67% fat), USDA High Choice (8.99% fat), and USDA Low Choice (5.56% fat), all had different fat contents (Corbin et al., 2015a). Consumers rated Low Choice samples as similar to USDA Prime for both tenderness and flavor liking, and both USDA Prime and USDA Low Choice as higher than USDA High Choice for tenderness (Corbin et al., 2015a). For flavor liking, USDA Low Choice and USDA High Choice were similar, but USDA Prime was scored higher than USDA High Choice (Corbin et al., 2015a). However, for both juiciness and overall liking, USDA Prime was rated higher than both USDA High and Low Choice, with the two Choice grades rated similar (Corbin et al., 2015a). These results may seem a bit unclear, but since the purpose of the study was to evaluate only samples considered tender based on WBSF values, it is clear why tenderness ratings were less aligned with the USDA quality grade.

It is important to consider other factors that could affect how consumers evaluate USDA Prime and other quality grades in strip loins. In a study by McKillip et al. (2017), consumers evaluated palatability traits in 3 USDA quality grades (USDA Prime, Low Choice, and Select) and additional steaks from each quality grade treatment were enhanced with a water, salt, and alkaline phosphate solution. For all sensory traits evaluated, regardless of quality grade, enhanced steaks outperformed non-enhanced steaks (McKillip et al., 2017). In the non-enhanced steaks, no differences were found between USDA Prime and Low Choice steaks for juiciness, tenderness, flavor, and overall liking (McKillip et al., 2017). For juiciness and tenderness, USDA Prime and Low Choice were rated higher than USDA Low Select steaks (McKillip et al., 2017). However, for flavor and overall liking, USDA Prime steaks were rated higher than USDA Select with USDA Low Choice steaks rated similar to both (McKillip et al., 2017).

In a similar study, Lucherk et al. (2016b) evaluated high and low enhanced USDA Select, Prime, Top Choice, Low Choice, Select, and Standard cooked to 3 degrees of doneness. In all three degrees of doneness consumer ratings, USDA Prime was rated similar to the high and low enhanced treatments (Lucherk et al., 2016b). The same was true in the trained sensory evaluation for initial juiciness and sustained juiciness. However, the results shifted for initial tenderness, sustained tenderness, and beef flavor intensity in the trained panels, with no significant interaction between the main effects of quality grade and degree of doneness. For initial juiciness and sustained juiciness, high enhanced USDA Select was rated the highest, followed by low enhanced USDA Select and Prime, which were similar (Lucherk et al., 2016b). The results shifted once again for beef flavor intensity, with USDA Prime the highest, followed by Top Choice, and both the enhanced USDA Select treatments having the lowest beef flavor intensity (Lucherk et al., 2016b).

With preferred cooking method by consumers as an important factor to consider, Sepulveda (2019) evaluated 4 USDA quality grades and 4 different cooking methods. The fat percentages for each of the quality grades were as follows: USDA Prime-10.6%, Top Choice-9.0%, USDA Low Choice-5.6%, USDA Select-3.6%. In the study, there was no interaction between the main effects of cooking method and quality grade. For tenderness, juiciness, flavor, and overall liking, USDA Prime steaks were similar to Top Choice steaks (Sepulveda, 2019). Additionally, USDA Prime steaks were rated higher than USDA Low Choice steaks for all palatability traits evaluated by consumers. Top Choice steaks only differed from USDA Low Choice for flavor liking (Sepulveda, 2019).

O'Quinn et al. (2012) had consumers evaluate USDA Prime, High Choice, Low Choice, Select, and Standard strip loin steaks for tenderness, juiciness, flavor, and overall liking, and were asked if each sample was acceptable for each of the palatability traits evaluated. In this study, strip loins were selected to represent each quality grade based off their fat percentage from proximate analysis. Consumers found tenderness, juiciness, flavor, and overall liking increased with increased quality grade, with USDA Prime being rated the highest (O'Quinn et al., 2012). Likewise, a higher percentage of samples were considered acceptable for each of the palatability traits evaluated at each increased quality grade, with USDA Prime having the highest percentage of acceptability (O'Quinn et al., 2012).

Impact of USDA Prime grade on eating quality in other muscles

Although most quality grade research is done in the *longissimus* due to the high repeatability and it is the muscle that gets evaluated for grading, there are studies that have evaluated other muscles. Legako et al. (2015b) evaluated consumer palatability ratings and volatile compounds of 5 USDA quality grades in four muscles. Starting with the *psoas major*, the fat percentage for each quality grade were as follows: USDA Prime- 8.1%, Top Choice- 6.9%, USDA Low Choice- 3.8%, USDA Select- 3.5%, and USDA Standard 2.9% (Legako et al., 2015b). Consumers found no differences for any of the quality grades for tenderness or flavor liking (Legako et al., 2015b). For juiciness and overall liking, no differences were found between all quality grades, except for USDA Low Choice (Legako et al., 2015b). For the *gluteus medius* muscle, the fat percentages were as follows: USDA Prime- 7.1%, Top Choice- 4.3%, USDA Low Choice- 1.6%, USDA Select- 2.9%, and USDA Standard- 2.6% (Legako et al., 2015b). For this muscle, there was no difference between quality grades for tenderness, juiciness, flavor, or overall liking (Legako et al., 2015b). Lasty, the *semimembranosus* muscle was evaluated with the following fat percentages USDA Prime- 5.6%, Top Choice- 5.0%, USDA Low Choice- 2.0%, USDA Select- 2.5%, and USDA Standard- 0.7% (Legako et al., 2015b). Once again, there were no differences between quality grades for tenderness (Legako et al., 2015b).

A study by Nyquist et al. (2018) evaluated USDA Prime, Choice, and Select quality grades in *longissimus thoracis, complexus, and spinalis dorsi, infraspinatus, serratus ventralis, triceps brachii, teres major, adductor, semimembranosus, and biceps femoris* for consumer sensory analysis. In the *infraspinatus, serratus ventralis,* and *adductor*, USDA Prime steaks outperformed both lower quality grades for the sensory traits evaluated by consumers (Nyquist et al., 2018). The *biceps femorus* and *semimembranosus* showed consumers rated USDA Prime samples similar to USDA Choice, but higher than USDA Select (Nyquist et al., 2018).

Beyer et al. (2021) studied 4 different quality grade's palatability traits in the *biceps femorus* in both consumer and trained panels. USDA Prime had 10.7% fat, Top Choice 8.0%, USDA Low Choice 7.2%, and USDA Select 5.7%, with Top Choice and USDA Low Choice as the only two treatments similar to each other (Beyer et al., 2021). They found consumers rated

USDA Prime steaks higher than USDA Low Choice and Select steaks but similar to Top Choice for flavor liking, but no differences were found for juiciness and tenderness (Beyer et al., 2021). USDA Prime steaks rated higher than all other quality grades for overall liking (Beyer et al., 2021). Trained panelists found no differences between quality grade treatments for myofibrillar tenderness or connective tissue amount. USDA Prime steaks were rated the highest for sustained juiciness and overall tenderness (Beyer et al., 2021). For initial juiciness, USDA Prime was similar to Top Choice (Beyer et al., 2021). No differences were found between USDA Prime, Top Choice, and USDA Low Choice for beef flavor intensity (Beyer et al., 2021).

In a study by Olson et al. (2019), top sirloin steaks from USDA Prime, Top Choice, USDA Low Choice, and Select were evaluated by consumer and trained panelists for palatability traits. It is important to note that at 9.0%, 8.8%, and 7.8% fat, USDA Prime, Top Choice, and USDA Low Choice did not differ in their fat percentage from proximate analysis (Olson et al., 2019). Consumers found no differences among quality grades for tenderness, flavor, and overall liking (Olson et al., 2019). USDA Prime was more juicy than USDA Low Choice and Select, with Top Choice being similar to USDA Prime, Low Choice, and Select (Olson et al., 2019). Trained panelists found no differences between quality grade treatments for connective tissue amount and overall tenderness, but had USDA Prime and Top Choice higher for beef flavor intensity than USDA Select (Olson et al., 2019).

The relationship between marbling and eating quality in beef is well established, with decades of research to support the relationship between the two. Several studies show that increased marbling results in increased perception of palatability traits such as tenderness, juiciness, and flavor (Smith et al., 1985; Thompson, 2004; O'Quinn et al., 2012). These findings are centered around the bite, strain, and lubrication theories dating back to 1974. These sensory benefits are typically found in the *longissimus* muscle, but can also be observed in other muscles, although sometimes at a lesser extent.

The impact of degree of doneness on eating quality

In the meat research discipline, the degrees of doneness (**DOD**) are established end-point temperatures used to cook steaks. Today, the end point temperatures commonly used are 55°C for very rare, 60°C for rare, 63°C for medium rare, 71°C for medium, 77°C for well done, and 82°C for very well done (NCBA, 2008). The impact of DOD on eating quality is a highly researched area, due to consumer's differing opinions on how they prefer their steaks cooked. Decker et al. (2024b) reported 10% of their consumer panelists preferred steaks rare, 47.5% preferred medium rare, 25% preferred medium, 13.3% preferred medium well, and 2.5% preferred well done. Many studies have shown different breakdowns of these preferred DODs by consumers. DOD is an important area as it directly relates to consumer satisfaction with their product. Cox et al. (1997) surveyed over 3,000 consumers eating in restaurants and found 30% of consumers thought their steak was not cooked to the DOD they ordered. If steaks were not served as their ordered DOD, all consumer palatability scores drastically declined (Cox et al., 1997). Furthermore, the study determined there was a much greater penalty in consumer satisfaction for steaks that were over-cooked from their ordered DOD than under-cooked (Cox et al., 1997).

Although specific temperatures are used in research to determine DOD, that is not the case for consumers or chefs in restaurants. Prill et al. (2019b) conducted a study aiming to determine if published cooking temperatures correspond with consumer and chef perceptions of DOD. When given a digital survey with pictures of 6 different DODs, consumers were able to identify the picture with the correct published DOD end-point temperature only 27-35% of the time (Prill et al., 2019b). When steaks were cooked to medium or lower DOD, chefs typically identified them as 1 DOD higher than what they actually were (Prill et al., 2019b). When steaks were cooked to well-done or very well-done, chefs typically identified the steaks as 1 DOD lower than what they actually were (Prill et al., 2019b). The same study found over 25% of the chefs surveyed said 6-10% of the steaks they cooked were returned due to the consumer being unhappy with the DOD their steak was cooked to (Prill et al., 2019b).

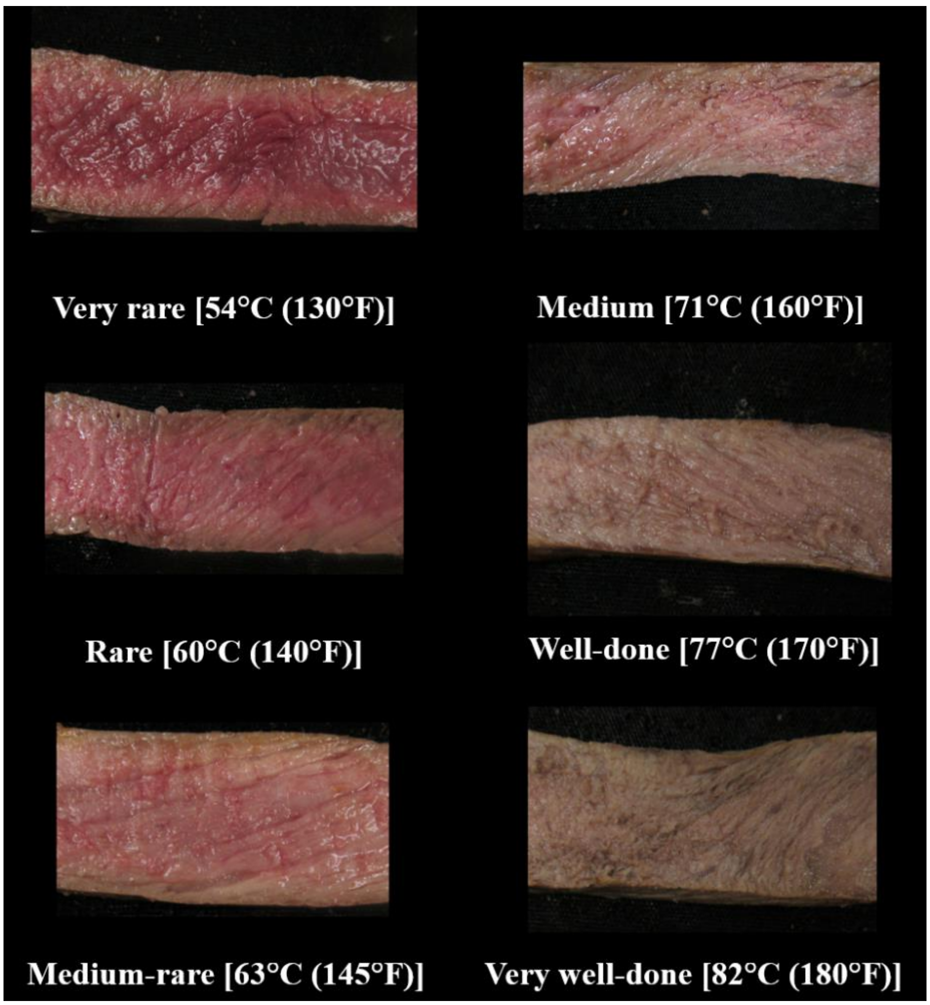

Figure 1.1 Representative DOD images evaluated by consumers and chefs (Prill et al., 2019).

Another study by Prill et al. (2019a) aimed to explore the impact of visual DODs on beef palatability in consumers with different DOD preferences. Consumers were pre-screened based on their preferred DOD and were assigned to panels based off that preference. Steaks were cooked to one of 5 DODs and were fed to consumers either under red light to mask DOD differences or under white light where DOD differences were visible. Under red light testing, rare and medium rare steaks were rated similar and higher than all other DOD for tenderness, juiciness, and flavor (Prill et al., 2019a). For those same traits, medium and medium-well were similar but higher than well-done (Prill et al., 2019a). Under white-light testing, the results were the same for tenderness and flavor. For juiciness, there was a stair-stepping effect with the higher DODs having lower ratings, and the only two DODs that were similar were rare and medium-rare (Prill et al., 2019a). The study also looked at overall liking of each of the DODs based on the consumers' preferred DOD. Under both lighting conditions, rare consumers had rare and medium-rare steaks rated the highest and medium-well and well-done the lowest (Prill et al., 2019a). Medium consumers had the same rankings as rare consumers under red light conditions, but under white-light had rare and medium-rare the highest and well-done as the lowest for overall liking (Prill et al., 2019a). The well-done consumers, however, found something vastly different than the other two groups. Under red-light, rare and medium-rare were similar and higher than medium-well and well-done for overall liking with medium being similar to both medium-well and well-done (Prill et al., 2019a). Conversely, under white-lighting the well-done consumers found no differences between DODs for overall liking (Prill et al., 2019a).

Lorenzen et al. (1999b) conducted an at-home study in various cities across the U.S. in which over 2000 consumers cooked top loin steaks at home and evaluated the steak for tenderness, juiciness, flavor intensity, flavor desirability, and overall liking. The study found consumers in San Francisco and Philadelphia cooked their steaks to lower DODs than those in Chicago and Houston (Lorenzen et al., 1999b). Consumers had the highest overall liking scores for steaks that were cooked to medium rare or less, and higher scores for medium and well-done or higher DODs when compared to a medium-well DOD (Lorenzen et al., 1999b). A similar study by McKenna et al. (2004) evaluated the same traits in consumers in San Antonio and Dallas. Consumers in Dallas tended to cook their steaks to higher DODs than those in San Antonio (McKenna et al., 2004). Regardless of city, steaks cooked to a medium-well DOD has the lowest ratings for the consumer palatability traits evaluated (McKenna et al., 2004).

Drey et al. (2019) found no interaction between 5 quality treatments and 6 DOD treatments in strip loin steaks. Regardless of the quality grade treatment, an increased DOD resulted in a decrease in consumer sensory ratings for tenderness, juiciness, flavor, and overall liking. Lorenzen et al. (2005), however, fed consumers strip loin steaks cooked to 6 different DODs and their consumers were unable to find differences in flavor or overall liking among degrees of doneness. Trained panelists in Lucherk et al. (2016b) found no differences between strip loin steaks cooked to rare, medium, and well-done for beef flavor intensity, but rated rare steaks higher than medium and well-done steaks for initial tenderness and sustained tenderness.

DOD has also shown to be an important factor for palatability characteristics in beef cuts other than strip loin steaks. Parrish et al. (1973) cooked ribeyes to 60°C, 70°C, and 80°C and had panelists evaluate the samples for flavor, tenderness, juiciness and acceptability. Panelists palatability ratings decreased linearly as DOD increased (Parrish et al., 1973). Milligan et al. (1997) cooked inside round roasts to 60°C, 70°C, and 80°C and had trained panelists evaluate them for different palatability traits. Overall, roasts cooked to 60°C received higher ratings that those cooked to 70°C and 80°C (Milligan et al., 1997).

O'Quinn et al. (2015) had consumers evaluate beef tenderloins cooked to very-rare, medium-rare, or well-done. Consumers rated very-rare and medium-rare steaks higher for juiciness when compared to well-done (O'Quinn et al., 2015). Additionally, consumers found very-rare steaks to be more tender than well-done steaks (O'Quinn et al., 2015). Olson et al. (2019) had consumers and trained panelists evaluate top sirloin steaks cooked to rare, medium, and well-done DODs. Consumers found with each decreased DOD that steaks were more tender, juicy, and liked the flavor and overall steak more (Olson et al., 2019). Trained panelists found the same results for overall tenderness, but found no differences between DODs for connective tissue amount and beef flavor intensity (Olson et al., 2019).

DOD has been shown to have a significant impact on eating quality and consumer satisfaction. Although different DODs are defined by their internal temperature, studies show a clear discrepancy between those internal temperatures and consumer and chef interpretations of those DODs. In general, consumers are more satisfied with steaks cooked lower than their preferred DOD than higher. Additionally, lower DOD tended to have higher palatability ratings than higher DODs. However, other factors, such as regional location, can also have an effect on consumer DOD preferences and perceptions.

Quality grade breakdown through time

The U.S. beef market has seen an increase in the quality of beef produced in the last 25 years (USDA-AMS, 2024). Figure 1.2 shows the percentage of carcasses that graded USDA Prime, Choice, and Select each year from 2000-2024. In the 24-year timespan, the percentage of carcasses grading USDA Prime has more than tripled, and there has been more than a 25% decrease in the number of carcasses grading USDA Select (Figure 1.2). Conversely, there has been over 17% increase in the number of carcasses grading USDA Choice, and over 7% increase in the number of carcasses grading USDA Prime (Figure 1.2). This shift in the grades was most notably seen in 2007, when the percentage of carcasses grading USDA Select began to decrease

(Figure 1.2). Although the full fiscal year report for 2025 is not completed yet, the most recent report from May shows for the first time since 1987, the percentage of carcasses grading USDA Prime has surpassed those grading USDA Select (USDA-AMS, 2025b). The report shows in the month of May, 13.3% of carcasses graded USDA Prime, while 12.3% of carcasses graded USDA Select. The numerical difference is not the key point, but the noticeable shift in the U.S. beef industry is, specifically within the USDA Prime grade. This shift is first seen in 2014, where there was an increase in the percentage of carcasses that graded USDA Prime each of the next 10 years (Figure 1.2). In those 10 years, the percentage of carcasses that graded USDA Prime has more than doubled (over 6% increase)(Figure 1.2).

It's not possible to talk about the shift in the quality of U.S. beef without talking about USDA Certified Beef Programs. The USDA (2025) has over 100 branded programs, with over 50 total brand names. These branded programs are primarily target for carcasses grading USDA Choice or better (USDA, 2025). As such, beef producers are aiming for these higher quality grades to capture the premiums that go along with these branded programs.

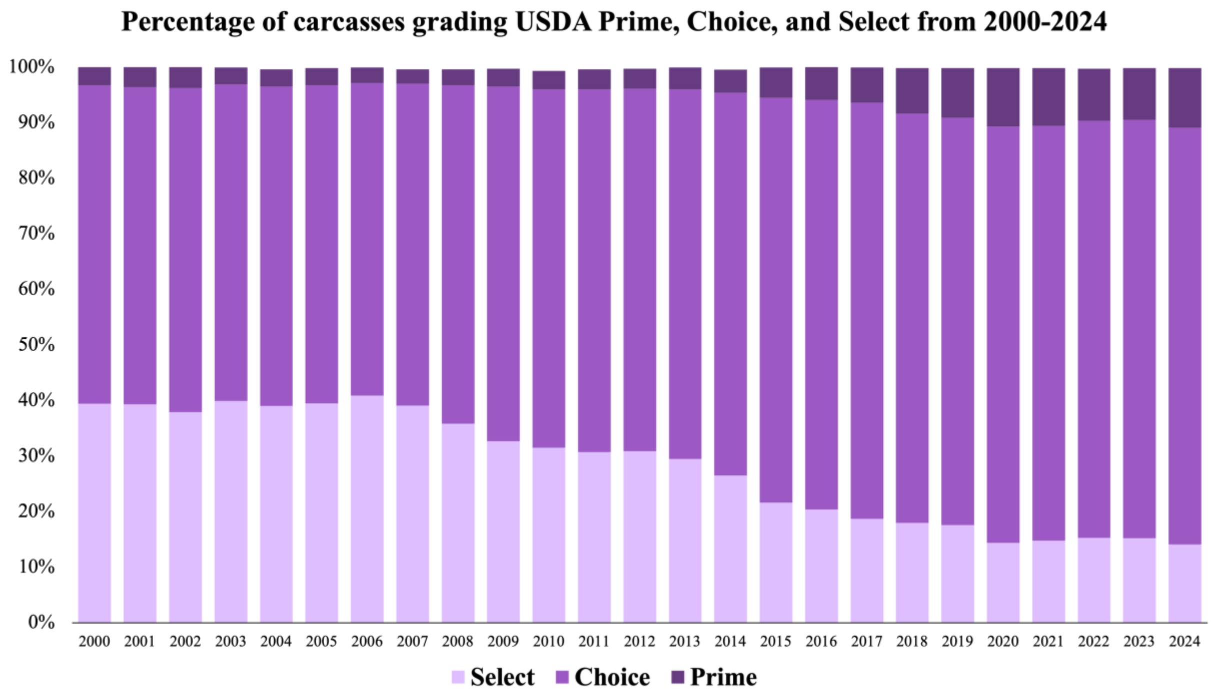

Figure 1.2 Percentage of carcasses grading USDA Prime, Choice, and Select from 2000-2024 (USDA-AMS, 2024).

Cutout value of carcasses through time

Not only has the U.S. beef market seen an increase in quality in recent years, but there has also been an increase in the value of beef in the United States (USDA-AMS, 2025a). Figure 1.3 shows the average value per hundredweight per year of USDA Prime, Choice, and Select carcasses for each year from 2002-2025. From 2002, USDA Prime carcasses have increased in value by more than $250/cwt, or a 33% increase (Figure 1.3). USDA Choice carcasses have seen a $208/cwt increase in value, or 35% increase (Figure 1.3). USDA Select carcasses have increased in value by $200/cwt, or 35% (Figure 1.3). Over this span of over two decades, there have been notable shifts in these cutout values. In 2002, the value of these different grades was relatively close together, with the value of each being within $18/cwt of each other. However, in today's beef market, the value of these grades differs by $70/cwt.

Within the last 5 years, there have been some big changes in the value of beef carcasses. Looking closer at Figure 1.3, from 2020 to 2021, each of the three quality grades represented had a big increase in their value. More specifically, USDA Prime carcasses increased in value by $66/cwt in that year alone (Figure 1.3). In the subsequent years, USDA Prime carcasses increased in value by a total of $127/cwt, or a 66% total increase (Figure 1.3). USDA Choice carcasses increased in value by $89/cwt, with a 72% increase (Figure 1.3). USDA Select carcasses increased in value by $83/cwt, with a 73% increase (Figure 1.3). Although the initial spike in price was likely due to the COVID-19 pandemic, there has still been a consistent increase in the value of beef in the years following.

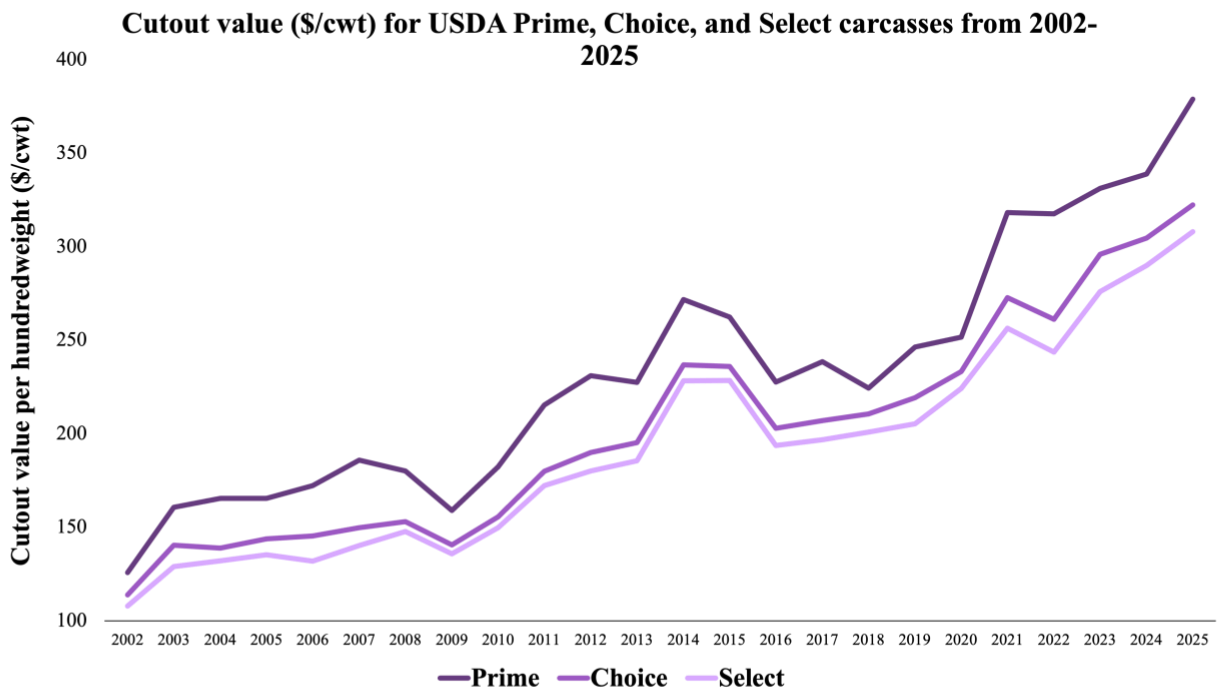

Figure 1.3 Cutout value ($/cwt) for USDA Prime, Choice, and Select carcasses from 2002-2025 (USDA-AMS, 2025a).

Cutout value difference of carcasses through time

Along with total value of carcasses increasing, there has been an increase in the per hundredweight difference in the value of the different grades over the last two decades (USDA-

AMS, 2025a). Figure 1.4 shows the difference in value between USDA Prime and Choice carcasses and USDA Prime and Select carcasses from 2002-2025. From 2002 to this year, the difference between USDA Prime and Choice carcasses has increased by 21% ($44/cwt) (Figure 1.4). In the same time frame, the spread between USDA Prime and Select carcasses has increased by almost $53/cwt, or 25% (Figure 1.4). At a closer look at the figure, there was a substantial decrease in the spread between these quality grades from 2007 to 2009 (Figure 1.4). During these 3 years, there was over 50% decrease in the spread between these quality grades, which corresponds to the shift in quality grades in Figure 1.2. Another notable shift in Figure 1.4 can be observed from 2020-2022. In this 3-year span, there was a $37/cwt increase in the spread between USDA Prime and Choice, and a $46/cwt increase in the spread between USDA Prime and Select carcasses (Figure 1.4).

Most recently, there has been a drastic increase in the spreads between quality grades from 2024 to 2025. In 2024, there was a $34/cwt difference between USDA Prime and Choice carcasses, and a $48/cwt difference between USDA Prime and Select carcasses (Figure 1.4). However, in 2025, there was a $56/cwt difference between USDA Prime and Choice carcasses, and a $70/cwt difference between USDA Prime and Select carcasses (Figure 1.4). That equates to a 60% and 68% increase, respectively.

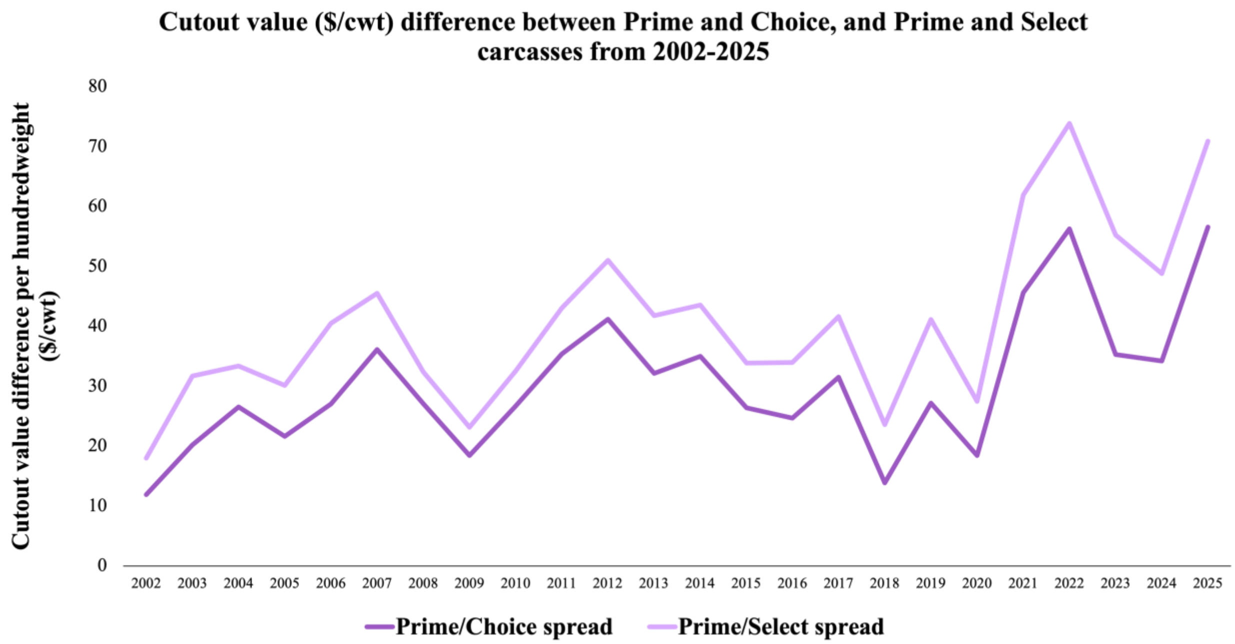

Figure 1.4 Cutout value ($/cwt) difference between USDA Prime and Choice, and USDA Prime and Select carcasses from 2002-2025 (USDA-AMS, 2025a).

Conclusion

The eating quality of beef can be influenced by a combination of factors including USDA quality grade, marbling content, DOD, and consumer preferences. Research shows a distinct relationship between consumer eating satisfaction and increased marbling content. Over recent decades, there has been a clear industry shift toward higher-quality beef to match this relationship. As a result, more carcasses are grading USDA Prime and Choice with fewer grading USDA Select, reinforcing the economic value of marbling through expanding price premiums and branded beef programs. Additionally, DOD has been shown to play a significant role in consumer satisfaction, impacting tenderness, juiciness, flavor, and overall acceptability. Continued research into these factors, particularly exploring the interplay between marbling level and DOD, is essential to further enhance beef quality and consistency, thereby ensuring sustained consumer satisfaction and economic returns within the beef industry.

References

Beyer, E. S., K. M. Harr, B. A. Olson, E. A. Rice, C. K. Jones, M. D. Chao, J. L. Vipham, M. D. Zumbaugh, and T. G. O'Quinn. 2021. Palatability traits of sirloin cap steaks from four USDA quality grades. Meat and Muscle Biology 5:1-10. doi:10.22175/mmb.12424

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. https://ttu-ir.tdl.org/ttu-ir/handle/2346/73425

Corbin, C., T. O'Quinn, A. Garmyn, J. Legako, M. Hunt, T. Dinh, R. Rathmann, J. Brooks, and M. Miller. 2015. Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments. Meat science 100:24-31.

Cox, R. J., J. M. Thompson, C. M. Cunial, S. Winter, and A. J. Gordon. 1997. The effect of degree of doneness of beef steaks on consumer acceptability of meals in restaurants. Meat science 45:75-85. doi:10.1016/S0309-1740(96)00080-0

Decker, L. K., E. S. Beyer, M. D. Chao, M. D. Zumbaugh, J. L. Vipham, and Travis G. O'Quinn. 2024. Effects of Thawing Method on Palatability Traits, Quality Attributes, and Thawing Characteristics of Beef Steaks. Meat and Muscle Biology 8.

Drey, L. N., L. L. Prill, B. A. Olson, E. A. Rice, J. M. Gonzalez, J. L. Vipham, T. A. Houser, E. A. E. Boyle, and T. G. O'Quinn. 2019. Evaluation of marbling and enhancement's abilities to compensate for reduced beef palatability at elevated degrees of doneness. Journal of Animal Science 97:669-686. doi:10.1093/jas/sky435

Emerson, M. R., D. R. Woerner, K. E. Belk, and J. D. Tatum. 2013. Effectiveness of USDA instrument-based marbling measurements for categorizing beef carcasses according to differences in longissimus muscle sensory attributes. Journal of Animal Science 91:1024-1034. doi:10.2527/jas.2012-5514

Farmer, K. J. 2022. Evaluation of the impact of bone-in versus boneless cuts on beef palatability. Master's Thesis, Kansas State University, Manhattan, KS. https://krex.k-state.edu/dspace/handle/2097/42052

Farmer, K. J., E. S. Beyer, S. G. Davis, K. M. Harr, K. R. Lybarger, L. A. Egger, M. D. Chao, J. L. Vipham, M. D. Zumbaugh, and T. G. O'Quinn. 2022. Evaluation of the impact of bone-in versus boneless cuts on beef palatability. Meat and Muscle Biology 6:1-13. doi:10.22175/mmb.15488

Legako, J., J. Brooks, T. G. O'Quinn, T. Hagan, R. Polkinghorne, L. Farmer, and M. Miller. 2015a. Consumer palatability scores and volatile beef flavor compounds of five USDA quality grades and four muscles. Meat science 100:291-300.

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

Lorenzen, C. L., V. K. Davuluri, K. Adhikari, and I. U. Grün. 2005. Effect of end-point temperature and degree of doneness on sensory and instrumental flavor profile of beef steaks. Journal of food science 70:S113-S118. doi:10.1111/j.1365-2621.2005.tb07114.x

Lorenzen, C. L., T. R. Neely, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, J. O. Reagan, and J. W. Savell. 1999. Beef customer satisfaction: cooking method and degree of doneness effects on the top loin steak. Journal of Animal Science 77:637-644. doi:10.2527/1999.773637x

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 science 122:145-154. doi:10.1016/j.meatsci.2016.08.005

McKenna, D. R., C. L. Lorenzen, K. D. Pollok, W. W. Morgan, W. L. Mies, J. J. Harris, R. Murphy, M. McAdams, D. S. Hale, and J. W. Savell. 2004. Interrelationships of breed type, USDA quality grade, cooking method, and degree of doneness on consumer evaluations of beef in Dallas and San Antonio, Texas, USA. Meat science 66:399-406.

McKillip, K. V., A. K. Wilfong, J. M. Gonzalez, T. A. Houser, J. A. Unruh, E. A. Boyle, and T. G. O'Quinn. 2017. Sensory evaluation of enhanced beef strip loin steaks cooked to 3 degrees of doneness. Meat and Muscle Biology 1.

McKinzie, T. B., A. J. Garmyn, C. C. McKinzie, M. Koohmaraie, J. F. Legako, D. R. Woerner, and M. F. Miller. 2025. Identifying Premium-Quality Beef in the United States—A Comparison of Beef Palatability from Grain-Finished Young and Mature Beef Cattle with Varying Marbling Scores. Foods. doi:https://doi.org/10.3390/foods14040676

Milligan, S. D., M. F. Miller, C. N. Oats, and C. B. Ramsey. 1997. Calcium chloride injection and degree of doneness effects on the sensory characteristics of beef inside round roasts. Journal of Animal Science 75:668-672. doi:10.2527/1997.753668x

NCBA. 2008. Beef steak color guide. National Cattelmen's Beef Association, Centennial, CO.

Nyquist, K. M., T. G. O'Quinn, L. N. Drey, L. W. Lucherk, J. Brooks, M. F. Miller, and J. F. Legako. 2018. Palatability of beef chuck, loin, and round muscles from three USDA quality grades. Journal of animal science 96:4276-4292.

O'Quinn, T. G., J. C. Brooks, and M. F. Miller. 2015. Consumer assessment of beef tenderloin steaks from various USDA quality grades at 3 degrees of doneness. Journal of food science 80:S444-S449. doi:10.1111/1750-3841.12775

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. Journal of Animal Science 90:626-634. doi:10.2527/jas.2011-4282

O'Quinn, T. G., J. F. Legako, J. C. Brooks, and M. F. Miller. 2018. Evaluation of the contribution of tenderness, juiciness, and flavor to the overall consumer beef eating experience1. Translational Animal Science 2:26-36. doi:10.1093/tas/txx008

Olson, B. A., E. A. Rice, L. L. Prill, L. N. Drey, J. M. Gonzalez, J. L. Vipham, M. D. Chao, and T. G. O'Quinn. 2019. Evaluation of beef top sirloin steaks of four quality grades cooked to three degrees of doneness. Meat and Muscle Biology 3:399-410. doi:10.22175/mmb2019.07.0022

Parrish, F. C., Jr., D. G. Olson, B. E. Miner, and R. E. Rust. 1973. Effect of degree of marbling and internal temperature of doneness on beef rib steaks. Journal of Animal Science 37:430-434. doi:10.2527/jas1973.372430x

Prill, L. L., L. N. Drey, B. A. Olson, E. A. Rice, J. M. Gonzalez, J. L. Vipham, M. D. Chao, P. D. Bass, M. J. Colle, and T. G. O'Quinn. 2019a. Visual degree of doneness impacts beef palatability for consumers with different degree of doneness preferences. Meat and Muscle Biology 3:411-423. doi:10.22175/mmb2019.07.0024

Prill, L. L., L. N. Drey, E. A. Rice, B. A. Olson, J. M. Gonzalez, J. L. Vipham, M. D. Chao, P. D. Bass, M. J. Colle, and T. G. O'Quinn. 2019b. Do published cooking temperatures correspond with consumer and chef perceptions of steak degrees of doneness? Meat and Muscle Biology 3:510-525. doi:10.22175/mmb2019.09.0040

Sepulveda, C. A., Garmyn, A. J., Legako, J. F., Miller, M. F. 2019. Cooking Method and USDA Quality Grade Affect Consumer Palatability and Flavor in beef strip Loin Steaks. Meat and Muscle Biology. doi:https://doi.org/10.22175/mmb2019.07.0031

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. National Academy Press, Washington, D.C. p 124-137.

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. 1985. Relationship of USDA marbling groups to palatability of cooked beef. Journal of Food Quality 7:289-308. doi:10.1111/j.1745-4557.1985.tb01061.x

Tatum, J. D., G. C. Smith, B. W. Berry, C. E. Murphey, F. L. Williams, and Z. L. Carpenter. 1980. Carcass characteristics, time on feed and cooked beef palatability attributes. Journal of Animal Science 50:833-840.

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

USDA. 2017. United States standards for grades of carcass beef. Untied States Department of Agriculture, Washington, DC.

USDA. 2025. Certified Beef Program Comparison (7/14/2025) - PDF Version. USDA - Agriculture Marketing Service.

USDA-AMS. 2024. Historical Beef Grading Data.

USDA-AMS. 2025a. Historical Cutout Data 2002-2025.

USDA-AMS. 2025b. May Grade Volume Report.

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 ratings of beef strip loin steaks. Journal of Animal Science 94:4930-4942. doi:10.2527/jas.2016-0893

Chapter 2 - Is it time for Super Prime?

Introduction

Over the past 25 years, the U.S. beef industry has seen a consistent improvement in carcass quality, most notably through an increased percentage of carcasses grading USDA Prime. During this time, the percentage of carcasses grading USDA Prime has more than tripled, now comprising more than 10% of the beef supply, and the percentage of carcasses grading USDA Choice has risen by more than 17% (USDA-AMS, 2024). As a result, the percentage of carcasses grading USDA Select has decreased by over 25% (USDA-AMS, 2024). Notably, for the first time since 1987, a recent USDA grading report indicated that the proportion of carcasses grading USDA Prime has surpassed those grading USDA Select (USDA-AMS, 2025b). This shift has been accompanied by a significant increase in carcass value, with USDA Prime carcasses now worth approximately 33% more than in 2002 (USDA-AMS, 2025a).

Despite ongoing changes in the beef industry, most value-based marketing programs still place their emphasis on carcasses grading **Average and High Choice**—commonly referred to as **Top Choice** or **Premium Choice**—while USDA Prime is typically marketed as a single, undifferentiated grade. For nearly 50 years, beginning with the introduction of **Certified Angus Beef® in 1978**, the industry has informally separated the USDA Choice grade into two groups: the **upper two-thirds (Premium or Top Choice)** and the **lower one-third (Low Choice)**. This distinction created a clear incentive for producers, as having cattle grade Premium Choice delivers the greatest economic return within the USDA Choice category. Today, the market reflects the importance of increased marbling, with a spread of **more than $50 per hundredweight (cwt)** between USDA Prime and USDA Choice carcasses (USDA-AMS, 2025a). Even with monetary reflection in the market, the beef industry has failed to reflect the shift in the USDA Prime grade that is available in the beef industry in premium programs for producers, as has been done in the USDA Choice grade for several decades.

As USDA Prime availability expands, there is a growing opportunity to better differentiate and capture added value from variation within the USDA Prime grade. However, most scientific studies evaluating the eating quality of USDA Prime have failed to segregate products within the grade, grouping all USDA Prime carcasses together regardless of whether they fall into upper two-thirds Prime (Average and High Prime) or lower one-third Prime (Low Prime). This lack of separation prevents the identification of potential differences in marbling distribution, fat quality, and the associated eating quality characteristics within the USDA Prime category. As a result, both industry pricing strategies and scientific evaluations may fail to capitalize on the true palatability potential and market value of the highest-marbling carcasses. Understanding and quantifying these differences could provide more precise tools for carcass valuation, improve consumer satisfaction, and support marketing programs that reward the very top end of beef quality.

Therefore, the objective of this study was to evaluate consumer palatability preferences for strip loin steaks from upper two-thirds Prime (Super Prime), Low Prime, upper two-thirds Choice (Top Choice), and Low Choice, across three degrees of doneness.

Materials and Methods

The protocols for the use of human subjects in sensory panel evaluations in this study were approved by the Kansas State University (**KSU**) Institutional Review Board (IRB 7440.10; July 2025).

Sample collection

An equal number (n = 15) of beef strip loin subprimals [IMPS #180, North American Meat Institute (2014)] representing four marbling categories were collected from a commercial beef processor in the Midwest. The four marbling categories were: Super Prime (Moderately Abundant, Abundant, and Very Abundant), Low Prime (Slightly Abundant), Top Choice (Moderate and Modest), and Low Choice (Small) (USDA, 2017). Lean maturity, skeletal maturity, and marbling scores were collected from carcasses by trained personnel from KSU (Appendix A). Strip loins were vacuum-packaged and transported to KSU. Subprimals were stored in covered carboard boxes at 2-4°C until fabrication. For fabrication, strip loins were cut into 2.54-cm-thick steaks. Within each strip loin, the most anterior steak ("face" steak) was assigned to proximate analysis, and sections of three consecutively cut steaks were randomly assigned one of three degrees of doneness (**DOD**): Rare (**R**, 60°C), Medium (**MED**, 71°C), and Well-Done (**WD**, 76°C). Within each DOD and quality treatment, steaks were assigned to the following evaluations: consumer sensory panel, trained sensory panel, or objective measurements. Samples designated for objective measurements were used for Warner-Bratzler Shear Force (**WBSF**), Slice Shear Force (**SSF**), pressed juice percentage (**PJP**), and cooking loss. After individual identification and vacuum-packaging, steaks were stored at 2-4°C until reaching 28-days postmortem and then frozen and stored at -20°C.

Cooking procedures

All steaks were thawed at 2-4°C prior to cooking and testing. Steaks were cooked on an electric flat top griddle (Model: 351GCPG48M, Cooking Performance Group, Lancaster, PA) to their pre-assigned DOD. A cast iron weighted steak press (8 × 4 in, 1.18 kg) was placed on top of steaks throughout cooking to ensure even cooking throughout. Type T thermocouples (Omega

Engineering, Inc., Stamford, CT) inserted in the geometric center of each steak plugged into 12 channel digital data loggers (Sper Scientific, Scottsdale, AZ) were used for temperature monitoring. Rare steaks were flipped at 27°C and pulled at 53°C for a peak temperature of 60°C. For a Medium DOD, steaks were flipped at 30°C and pulled from the grill at 68°C for a peak temperature of 71°C. Well-Done steaks were flipped at 32°C and pulled at 74°C for a peak temperature of 76°C. All final peak temperatures were recorded. Prior to cooking, steaks were trimmed to remove all external fat, connective tissue, and additional muscles so only the *longissimus lumborum* remained. All cooking procedures remained the same throughout the study.

Consumer sensory analysis

Consumers (n = 64 / DOD) were recruited from Manhattan, Kansas and nearby surrounding communities based on their preferred DOD and monetarily compensated for their participation. Twelve sessions of 16 consumers were conducted within the same week, 4 sessions per degree of doneness. Panels were conducted in a large lecture-style classroom with fluorescent lighting and lasted approximately 1 h.

Consumers were given an electronic tablet (Fire HD 8; Amazon, Seattle, WA) to record their answers on a digital survey (Qualtrics Software, Provo, UT), as well as an expectorant cup, apple juice, water, and unsalted crackers as palate cleansers. Prior to beginning the session, panelists were given verbal instructions on how to fill out the survey, testing procedures, and how to utilize the palate cleansers. The digital survey began with demographic information questions regarding gender, age, ethnicity, marital status, household size, income, education, palatability and DOD preferences, and weekly beef consumption. Next, panelists were asked a series of questions on the importance of different factors regarding label claims and product characteristics when purchasing fresh beef steaks. These questions were asked on a 100-point continuous line scale with anchors at 0 being extremely unimportant, and 100 being extremely important.

For the first 3 panels per DOD, individuals were fed 8 samples, two from each quality grade treatment of their preferred DOD. The last panel of 8 consumers in each DOD were only fed 4 samples, one from each quality grade treatment. Consumers evaluated samples for tenderness, juiciness, flavor liking, and overall liking on 100-point continuous line scales. Anchors were given on both ends and at the midway point with 0 being extremely dry/tough/dislike extremely, 50 being neither juicy nor dry/neither tough nor tender/neither like nor dislike, and 100 being extremely juicy/tender/like extremely. Consumers were also asked if each sample was acceptable (yes/no) for each of the sensory traits evaluated. Samples were prepared as described above. Samples were cut into 1.3 × 1.3 × 2.54 cm cubes and consumers were fed two cubes per sample.

Trained sensory analysis

Panelists were trained using training procedures outlined by the American Meat Science Association (**AMSA**) Sensory Guidelines (AMSA, 2016). Six 30-min training sessions occurred over the course of one week immediately prior to the start of panels using anchors and methods as described by Lucherk et al. (2017) and Vierck et al. (2019).

Twenty-four sessions separated by DOD (8 / DOD) consisting of 8 panelists occurred. For the first 7 sessions per DOD, panelists were fed 8 samples in a random order, two from each quality grade treatment group. In the last session per DOD, panelists were only fed 4 samples, one from each quality grade treatment group. Before each session began, a warm-up sample was fed and discussed among panelists to reduce panel drift. Panelists were fed in booths under red lighting to mask any color differences and reduce bias. Panelists were given apple slices, unsalted crackers, and water as palate cleansers as well as an expectorant cup. Samples were evaluated for initial juiciness, sustained juiciness, myofibrillar tenderness, connective tissue amount, overall tenderness, beef flavor intensity, and off-flavor intensity on a 100-point continuous line scale. Anchors were given at both ends with 0 being extremely dry/tough/bland/none and 100 being extremely juicy/tender/abundant/intense and 50 serving as the neutral point. Additionally, for off-flavor intensity, there was a "not applicable" option. If there was an off-flavor present, panelists were directed to a question asking them to describe the off-flavor present. Responses were recorded on an electronic tablet (Fire HD 8; Amazon, Seattle, WA) using a digital survey (Qualtrics Software, Provo, UT). Samples were prepared as described above. Upon preparation, samples were cut into 1.3 × 1.3 × 2.54 cm cubes. Panelists were fed two cubes per sample.

Objective measurements

On the same day, steaks assigned for cooking loss, WBSF, SSF, and PJP were cooked as described above. Steaks were weighed before cooking and after cooking to calculate the percentage of cook loss.

After cooking, samples were prepared for SSF analysis as described by Shackelford et al. (1999) . First, a small portion was cut from the lateral end of the steak to determine the muscle fiber orientation followed by a second cut 5 cm from the initial cut. From that piece, a double-bladed knife was used to cut a 1 cm x 5 cm piece at a 45-degree angle. The sample was sheared using a flat blade perpendicular to the muscle fiber in the middle of the sample using the SSF machine (Model GR152; Tallgrass Solutions, Manhattan, KS). The peak force was recorded.

Samples were prepared for PJP analysis as described by Lucherk et al. (2017). Immediately medial to the SSF piece, an additional 1 cm-thick slice was cut into an additional three 1 cm-wide pieces cut parallel to the muscle fiber orientation. Two pieces of filter paper (Fisher brand Filter Paper P8, 12.5 cm, Pittsburg, PA) were weighed, a sample was placed between the papers and weighed again. The sample and filter paper were compressed (Instron Model 5569, Canton MA) at 8.0 kg, and the filter paper without the sample was weighed again. The three replications were averaged from each sample to determine the PJP.

The remainder of the steak was refrigerated for 24 hours at 2-4°C for WBSF analysis. Protocols used followed the AMSA (American Meat Science Association, 2016) Sensory Guidelines. The following day, six 1.27-cm diameter cores were taken parallel to the longitudinal muscle fiber orientation. Samples were sheared using an Instron (Instron Model 5569, Canton MA) perpendicular to the muscle fiber with a V-shaped blade with a crosshead speed of 250 mm/min with a load cell of 100 kg. All 6 samples were sheared with the maximum force recorded (kg) and averaged for each steak.

Proximate analysis

Frozen samples designated for proximate analysis were thawed at 2-4°C for 24 h before analysis. Raw samples were trimmed of all external fat, connective tissue, and additional muscles so only the *longissimus lumborum* muscle remained. Samples were cut into 1 cm thick slices and ground into an electric tabletop meat grinder (STX International, Lincoln, NE). The ground sample was packed into a petri dish (VWR International, Randor, PA) so there was no air bubbles or light showing through the bottom. Samples were analyzed using a FoodScan 2 (FOSS Analytical, Capital Region, Denmark). The percentage of protein, fat, moisture, and ash was recorded for each sample.

Statistical analysis

The statistical procedures were conducted using SAS (Version 9.4; SAS Inst., Inc., Cary, NC) PROC GLIMMIX using a split-plot model with statistical significance considered with an *a* of 0.05. Quality grade treatment served as the whole plot factor with DOD as the sub-plot factor. Panel session was accounted for as a random effect. Consumer acceptability data were analyzed with a binomial error distribution model. The Kenward-Roger adjustment was used in all analyses.

Results

Consumer demographic and purchasing motivators

Consumer demographics are shown in Table 2.1. There were more females (67%) than males (33%) represented. The majority of consumers came from a household size of 2 people (40.1%). However, there were more single (58.4%) than married (41.6%) individuals represented. Most consumers were between the age of 20-29 (29.2%) or > 60 years old (21.9%). The vast majority of consumers were Caucasian/white (82.8%), although African American, Asian, Latino, and Native American ethnicities were all represented. Most consumers had a household income level of at least $50,000 (58.9%). Additionally, 97.9% of consumers had at least a high school diploma. Most consumers found flavor (56.2%) to be the most important palatability trait when consuming beef. However, most consumers identified tenderness (47.6%) as the most variable palatability trait when consuming beef. Medium-rare (54.7%) was the most commonly preferred DOD. Most (42.6%) consumers ate beef 1-3 times per week.

Consumer purchasing motivators are shown in Table 2.2. “Price” was more important ($P < 0.05$) when purchasing fresh beef steaks than all other traits except “size, weight, and thickness". "Natural or Organic", "animal fed a corn-based diet", "packaging type", and "brand of product" were the least important ($P < 0.05$) traits to consumers when purchasing beef.

Consumer sensory analysis

Consumer sensory ratings are shown in Table 2.3. There were no ($P > 0.05$) interactions between quality grade and DOD for any consumer-evaluated traits. When evaluating the main effect of quality grade, Super Prime steaks were juicier, more tender, and rated higher for flavor and overall liking ($P < 0.05$) than all other grades. No differences ($P > 0.05$) were found among Low Prime, Top Choice, and Low Choice steaks for juiciness, flavor, and overall liking. Tenderness ratings were similar ($P > 0.05$) between Low Prime and Top Choice and between Top Choice and Low Choice. However, Low Prime steaks rated higher ($P < 0.05$) than Low Choice steaks for tenderness. Additionally, a higher percentage of Super Prime steaks were rated acceptable ($P < 0.05$) for juiciness, tenderness, flavor, and overall liking than all lower grades (Table 2.4). No differences ($P > 0.05$) were found in the percentage of samples rated acceptable for tenderness between Low Prime and Top Choice and between Top Choice and Low Choice. However, a higher percentage ($P < 0.05$) of consumers rated Low Prime steaks as acceptable for tenderness than Low Choice.

When evaluating the impact of DOD, Rare steaks were juicier, more tender, and rated higher overall ($P < 0.05$) than Medium and Well-done steaks (Table 2.3). However, Medium and Well-done steaks rated similar ($P > 0.05$) for juiciness, tenderness and overall liking. No differences ($P > 0.05$) were found between Rare and Medium steaks, and between Medium and Well-done steaks for flavor liking. However, Rare steaks were rated higher ($P < 0.05$) than Well-done steaks for flavor liking. Additionally, a higher percentage ($P < 0.05$) of Rare steaks were rated acceptable for juiciness than Medium steaks, and a higher percentage ($P < 0.05$) of

Medium steaks were rated acceptable for juiciness than Well-done steaks (Table 2.4). A higher percentage ($P < 0.05$) of Rare steaks were classified as acceptable for tenderness than Medium and Well-done. However, there was no difference ($P > 0.05$) in the percentage of Medium and Well-done steaks that rated acceptable for tenderness. For overall acceptability, no differences ($P > 0.05$) were found in the percentage of samples rated acceptable between Rare and Well-done steaks or between Well-done and Medium. However, a higher percentage ($P < 0.05$) of Well-done steaks were rated as acceptable than Medium for overall acceptability. DOD had no impact ($P > 0.05$) on the percentage of samples rated acceptable for flavor liking.

Trained sensory analysis

Trained sensory data is presented in Table 2.5. There were no ($P > 0.05$) interactions between quality grade and DOD for any trained panel-evaluated traits. When evaluating the main effect of quality grade, trained panelists found Super Prime steaks to have a higher ($P < 0.05$) initial juiciness, sustained juiciness, myofibrillar tenderness, overall tenderness, and beef flavor intensity than all other quality grades. Low Prime samples were juicier ($P < 0.05$), both initially and sustained, when compared to Low Choice. However, there were no differences ($P > 0.05$) between Low Prime and Top Choice, and between Top Choice and Low Choice for initial or sustained juiciness. There were no differences ($P > 0.05$) among Low Prime, Top Choice, or Low Choice for myofibrillar tenderness, connective tissue amount, and overall tenderness. Super Prime steaks were rated lower ($P < 0.05$) than all other quality grades for connective tissue amount. Low Prime and Top Choice steaks were similar ($P > 0.05$), but higher ($P < 0.05$) than Low Choice samples for beef flavor intensity.

When evaluating the impact of DOD, Rare and Medium samples were similar ($P > 0.05$) for initial juiciness, myofibrillar tenderness, and overall tenderness. Rare steaks were rated higher ($P < 0.05$) than Medium for sustained juiciness. Well-done samples were rated the lowest ($P < 0.05$) for initial juiciness, sustained juiciness, myofibrillar tenderness, and overall tenderness when compared to all other DODs. There were no differences ($P > 0.05$) among DODs for connective tissue amount or beef flavor intensity.

Objective measurements

Objective measurement results are shown in Table 2.6. There was an interaction ($P < 0.05$) between quality grade and DOD for WBSF, SSF, PJP, and cook loss. In each DOD, Super Prime steaks had the lowest ($P < 0.05$) WBSF values when compared to the other quality grades. Within the Rare treatment group, Low Choice had the highest ($P < 0.05$) WBSF value, with Low Prime and Top Choice similar ($P > 0.05$). Low Choice and Top Choice steaks cooked to Medium had similar ($P > 0.05$), but higher ($P < 0.05$) WBSF values than Low Prime. For Well-done, Top Choice and Low Choice samples had similar ($P > 0.05$) WBSF values, but were higher ($P < 0.05$) than Low Prime.

There were no differences ($P > 0.05$) among quality grade treatments cooked to Rare for SSF. Steaks cooked to Medium had no differences ($P > 0.05$) among Low Choice, Top Choice, and Low Prime for SSF. Super Prime steaks cooked to Medium were similar ($P > 0.05$) to Low Prime, but lower ($P < 0.05$) than Top Choice and Low Choice for SSF. For Well-done, Low Prime and Top Choice samples had similar ($P > 0.05$) SSF values but were higher ($P < 0.05$) than Low Choice. Super Prime had the lowest ($P < 0.05$) SSF values when compared to all other quality grade treatments.

There were no differences ($P > 0.05$) among quality grade treatments cooked to Rare for PJP. Super Prime steaks cooked to Medium had a higher ($P < 0.05$) PJP than all other quality grades, with no differences ($P > 0.05$) between Low Prime, Top Choice, and Low Choice. Super

Prime steaks cooked to Well-done had a higher ($P < 0.05$) PJP than Top Choice. There were no differences ($P > 0.05$) in PJP values among Super Prime, Low Prime, and Low Choice. No differences ($P > 0.05$) were found among Low Prime, Top Choice, and Low Choice for PJP.

There were no differences ($P > 0.05$) among quality grades treatments cooked to Rare for cook loss. Super Prime steaks cooked to Medium had the lowest ($P < 0.05$) cook loss when compared to all other quality grades. There were no differences ($P > 0.05$) among Low Prime, Top Choice, and Low Choice steaks cooked to Medium for cook loss. Well-done Top Choice steaks had a higher ($P < 0.05$) cook loss when compared to Super Prime. There were no differences ($P > 0.05$) in cook loss among Well-done Super Prime, Low Prime, and Low Choice. No differences ($P > 0.05$) were found in cook loss for Low Prime, Top Choice, and Low Choice cooked to Well-done.

Proximate analysis

Proximate analysis results are shown in Table 2.7. Fat percentage aligned with quality grade treatments (Super Prime > Low Prime > Top Choice > Low Choice; $P < 0.05$). Moisture percentage showed an increase ($P < 0.05$) with each decrease in quality grade (Super Prime < Low Prime < Top Choice < Low Choice). Low Choice and Top Choice, and Top Choice and Low Prime samples had similar ($P > 0.05$) protein percentages. Low Choice had a higher ($P < 0.05$) protein percentage than Low Prime, and Low Prime had a higher ($P < 0.05$) protein percentage than Super Prime. Super Prime and Top Choice had similar ($P > 0.05$) ash percentages. There were no differences ($P > 0.05$) between Top Choice and Low Choice ash percentages. Low Prime and Low Choice had similar ($P > 0.05$) ash percentages. Super Prime had a higher ($P < 0.05$) ash percentage than Low Choice and Low Prime.

Discussion

Degree of doneness

Degree of doneness is a critical factor influencing beef palatability and has been extensively researched, with elevated degrees of doneness typically associated with decreased eating quality (Cox et al., 1997; Lorenzen et al., 1999a; McKenna et al., 2004; Drey et al., 2019; Olson et al., 2019; Prill, 2019). Across studies, DOD is consistently shown to be inversely related to ratings of tenderness, juiciness, flavor, and overall acceptability, with lower DODs generally receiving more favorable ratings (Parrish et al., 1973; Drey et al., 2019). At the same time, consumer preferences for DOD vary considerably and can directly influence evaluations. Past consumer studies show the variation in consumer DOD Preferences. Previous studies reported 3.9-10% consumers prefer Rare, 41.1-47.5% consumers prefer Medium-rare, 23.1-34.2% prefer Medium, 11.6-17.6% prefer Medium-well, and 2.5-6.7% prefer well-done (Prill et al., 2019b; Beyer et al., 2021; Decker et al., 2024a). The current study followed a similar pattern with the majority of consumers preferring a medium-rare DOD and the fewest consumers preferring well-done. Thus, it's important to understand how DOD preference of consumers drives the eating quality of steaks.

In the current work, there were no significant quality grade × DOD interactions for either trained or consumer sensory evaluations which is similar to the findings of Drey et al. (2019), McKillip et al. (2017), and Lucherk et al. (2016a). However, these studies found very different results for consumer sensory evaluation for DOD in comparison to the current study. McKillip et al. (2017) found differences between each of their DOD treatments for all traits evaluated by consumers for ratings and acceptability, except flavor, while our study found medium and well-done to be similar for all traits. But, the McKillip et al. (2017) study used different DOD treatments than the current work, having fed very well-done as opposed to well-done as in the current study. Drey et al. (2019) also found more differences among DOD treatments than the current study but had 6 different DOD treatments as opposed to the 3 in the current study. Lucherk et al. (2016a) fed consumers different quality grades to three DODs but did not compare results across DODs. Consumers found mixed results, with rare steaks being rated 5-29% higher than well-done for juiciness across the different quality grades, but tenderness, flavor, and overall liking showed different results (Lucherk et al., 2016a). USDA Prime were rated 9-12% higher at well-done than rare, while Low Choice was 3-5% higher at rare than well-done for tenderness, flavor, and overall liking (Lucherk et al., 2016a). Each of these studies also took a different approach to feeding consumers different DODs. While Lucherk et al. (2016a) took the same approach as the present study in which consumers were pre-screened for their preferred DOD and only fed that DOD, McKillip et al. (2017) and Drey et al. (2019) fed consumers under red lights to mask DOD differences. These differences in methodology could account for the discrepancies in observed results across studies. However, collectively these studies provide evidence of the independence of the impact of marbling and degree of doneness on eating quality, with marbling having the same impact on eating quality at multiple DOD when evaluated by consumer sensory panelists.

Olson et al. (2019) also studied the interaction between quality grade and DOD, though in top sirloin steaks rather than strip loin steaks. Similar to the current study, they reported no interaction in consumer evaluations. However, their trained sensory panelists observed interactions for myofibrillar tenderness, initial juiciness, and sustained juiciness - results that differ from ours. McKillip et al. (2017) also found a quality grade × DOD interaction for initial juiciness, but not for any other trait evaluated by trained panelists. Lucherk et al. (2016a) and

Drey et al. (2019) found a quality grade × DOD interaction for both initial and sustained juiciness. Despite these differences, Olson et al. (2019), McKillip et al. (2017), and the present study found no differences in connective tissue amount or beef flavor intensity across DOD treatments, suggesting these attributes are less influenced by cooking degree than traits such as tenderness or juiciness.

Instrumental measures did, however, reveal significant quality grade × DOD interactions for WBSF, SSF, PJP, and cook loss in the present study. In the current study, cooking steaks to rare had less of an impact on objective measurements than cooking steaks to well-done. Prior research on these measures has produced mixed results. Lucherk et al. (2016a) reported a significant interaction for SSF in strip loins, while McKillip et al. (2017) and Drey et al. (2019) found no such interaction between marbling level and DOD. In the current study, the impact of marbling in SSF, PJP, and cook loss was less pronounced in steaks cooked to Rare than the other two DODs. Notably, no previous study has documented a quality grade × DOD interaction for WBSF, making the present results noteworthy and highlighting the need for additional research to further explore this relationship.

Marbling

The influence of marbling on palatability is well established in previous literature (Smith et al., 1985; O'Quinn et al., 2012; Emerson et al., 2013; Corbin et al., 2015b). Higher USDA quality grades are consistently associated with improved eating experiences, and the strip loin has been the cut of choice for many studies due to its repeatability and consistency. Several researchers have specifically evaluated consumer and trained panelist responses to USDA Prime (Cashman et al., 2015; Corbin et al., 2015b; Lucherk et al., 2016a; Wilfong et al., 2016). However, Emerson et al. (2013) and Smith et al. (1987) are the only studies to date that subdivided USDA Prime, comparing Moderately Abundant (Average Prime) and Slightly Abundant (Low Prime) with lower quality grades. Emerson et al. (2013) reported a 5% increase in juiciness between Moderately Abundant and Slightly Abundant but found no differences in tenderness. This differs from the current study, where trained panelists rated Super Prime steaks (a combination of Moderately Abundant and Abundant) 13-19% higher for all traits evaluated when compared to USDA Low Prime (Slightly Abundant).

Although minimal previous work has separated the USDA Prime grade, there is extensive research that has separated the USDA Choice grade into Premium or Top Choice and Low Choice (Lorenzen et al., 2003; O'Quinn et al., 2012; Martinez et al., 2017; Drey et al., 2019; Lucherk et al., 2022). Despite the extensive amount of previous work comparing these two grade categories, the results from these studies are mixed. While O'Quinn et al. (2012) found Top Choice strip loin steaks to be more tender, juicy, flavorful, and rated higher overall when compared to Low Choice for consumer ratings, Lucherk et al. (2022) and Drey et al. (2019), as well as the current study, found no difference in consumer sensory ratings between Top Choice and Low Choice. In the latest National Beef Tenderness Survey, there were no differences in WBSF values between Top Choice and Low Choice (Martinez et al., 2017). Despite these mixed results, there is over a $13/cwt difference between Top Choice and Low Choice carcasses (USDA-AMS, 2025c). The current study shows undisputed improvement across measurements between Super Prime and USDA Low Prime, supporting the need to mimic the separation of the USDA Choice grade in the USDA Prime grade.

Corbin et al. (2015b) reported fat percentages of 14.7% for USDA Prime, 9.0% for USDA High Choice, 5.56% for USDA Low Choice, and 3.31% for USDA Select. These values closely parallel the fat percentages in the current study: 13.7% for Super Prime, 9.7% for USDA

Low Prime, 5.8% for Top Choice, and 4.0% for USDA Low Choice. Despite differences in classification, the patterns in both studies were similar. Corbin et al. (2015b) found that USDA Prime was rated higher than other grades for tenderness, juiciness, and overall liking, with no differences between USDA High and Low Choice. Vierck et al. (2018) also found no differences between Top Choice and USDA Low Choice for consumer palatability and acceptability ratings, much like the present study. However, unlike our findings, Corbin et al. (2015b) observed similar acceptability percentages between USDA Prime and High Choice across tenderness, flavor liking, and overall liking.

In the current study, consumers rated Super Prime steaks 19% higher for juiciness than USDA Low Prime and 23% higher than Top Choice. By contrast, O'Quinn et al. (2012), who did not subdivide USDA Prime into two groups like the current study, found only a 6% juiciness advantage of USDA Prime over USDA High Choice. Similarly, for tenderness, Super Prime was rated 15% higher than Low Prime and 25% higher than Top Choice in our study, whereas Legako et al. (2015b) reported no difference between USDA Prime and Top Choice. Flavor liking followed the same pattern: Super Prime was rated 13% higher than USDA Low Prime and 16% higher than Top Choice, while Drey et al. (2019) found only a 10% increase between USDA Prime and Top Choice. Overall liking ratings also reflected this trend, with Super Prime rated higher than USDA Low Prime by 14% and Top Choice by 19%. Lucherk et al. (2016a) found no differences between USDA Prime and Top Choice for overall liking. Taken together, these results demonstrate the potential of separating USDA Prime into two categories like the USDA Choice grade, as Average and High Prime categories produce substantially improved consumer perceptions of eating quality.

Conclusion

Overall, regardless of DOD, Super Prime steaks were rated higher than all other quality grades across every sensory trait evaluated by both consumers and trained panelists. The impact of marbling was consistent across DODs, with Super Prime steaks being rated the highest for all palatability characteristics. These findings provide strong evidence that consumers prefer the eating quality of upper two-thirds Prime steaks over other grades. With a spread exceeding $50/cwt between USDA Prime and USDA Choice carcasses—and with Prime availability at record levels—there is a clear opportunity for the beef industry to capture additional value from today's high-quality beef supply. These findings support the need for the establishment of a premium program within the USDA Prime grade, positioning the beef industry to leverage the improved quality of beef that is being produced today.

Table 2.1 Demographic characteristics of consumer panelists ($N = 192$) who participated in consumer sensory panels.

Characteristic	Response	Percentage of consumers
Gender	Male	33.0
	Female	67.0
Household Size	1 person	19.8
	2 people	40.1
	3 people	9.9
	4 people	12.0
	5 people	10.4
	6 people	3.6
	> 6 people	4.2
Marital Status	Married	41.6
	Single	58.4
Age	< 20	16.1
	20-29	29.2
	30-39	15.6
	40-49	9.4
	50-59	7.8
	> 60	21.9
Ethnic Origin	African American	1.6
	Asian	2.6
	Caucasian/white	82.8
	Latino	4.7
	Mixed race	2.6
	Native American	1.0
	Other	4.7
Household income level	< $25,000	19.5
	$25,000-$34,999	6.3
	$35,000-$49,999	15.3
	$50,000-$74,999	13.7
	$75,000-$99,999	15.3
	$100,000-$149,999	15.3
	$150,000-$199,999	8.4
	> $199,999	6.2
Education level	Non-high school graduate	2.1
	High school graduate	18.2
	Some college/technical school	33.3
	College graduate	27.1
	Post-college graduate	19.3
Most important palatability trait when consuming beef	Tenderness	31.8
	Juiciness	12.0
	Flavor	56.2
Most variable palatability trait when consuming beef	Tenderness	47.6
	Juiciness	27.7
	Flavor	24.7
Preferred degree of doneness when consuming beef	Very rare	0.5
	Rare	6.8
	Medium-Rare	54.7
	Medium	24.0
	Medium-Well	10.4
	Well-Done	3.6
Weekly beef consumption	0 times	0.0
	1-3 times	42.6
	4-6 times	34.8
	7-9 times	10.0
	> 10 times	12.6

Table 2.2 Fresh beef steak purchasing motivators of consumers (N = 192) who participated in sensory panels.

Characteristic	Importance of each trait[1]
Price	75.1[a]
Size, weight, and thickness	70.4[ab]
Marbling	67.8[bc]
Color	67.3[bc]
Nutrient Content	63.1[cd]
USDA Grade	62.8[cde]
Familiarity with cut	60.3[def]
Eating Satisfaction claims	57.5[ef]
Animal Welfare claims	55.4[fg]
Growth hormone use	51.2[gh]
Fresh Never Frozen	50.9[gh]
Antibiotic use in the animal	50.4[gh]
Animal fed a forage-based diet	46.2[h]
Natural or Organic	39.6[i]
Animal fed a corn-based diet	39.4[i]
Packaging Type	39.3[i]
Brand of Product	39.1[i]
SEM[2]	2.0
P - value	< 0.01

[abcdefghi] Least squares means without a common superscript differ ($P < 0.05$).

[1] Purchasing motivators: 0 = extremely unimportant, 100 = extremely important.

[2] SEM (largest) of the least square means.

Table 2.3 Least squares means of consumer (n = 64 / degree of doneness) panel palatability ratings[1] for strip loin steaks across 4 marbling categories and 3 degrees of doneness.

Treatment	Juiciness	Tenderness	Flavor liking	Overall liking
Quality grade[2]				
Super Prime	74.3^{a}	75.6^{a}	70.6^{a}	73.6^{a}
Low Prime	62.5^{b}	65.6^{b}	62.5^{b}	64.4^{b}
Top Choice	60.0^{b}	60.5^{bc}	60.9^{b}	61.8^{b}
Low Choice	59.4^{b}	59.5^{c}	59.9^{b}	60.9^{b}
SEM[4]	2.0	2.1	1.6	1.8
P-value	< 0.01	< 0.01	< 0.01	< 0.01
Degree of doneness[3]				
Rare	69.0^{a}	69.3^{a}	66.9	69.4^{a}
Medium	63.6^{b}	63.3^{b}	60.9	62.8^{b}
Well-done	59.5^{b}	63.3^{b}	62.7	63.3^{b}
SEM[4]	2.4	1.8	1.9	1.7
P-value	< 0.01	0.02	0.08	< 0.01

[abc] Least squares means within the same section of the same column without a common superscript differ ($P < 0.05$).

[1] Sensory scores: 0 = extremely dry/tough/dislike extremely, 50 = neither dry nor juicy, neither tough nor tender, neither like nor dislike, 100 = extremely juicy/tender/like extremely.

[2] Marbling scores: Super Prime - Moderately Abundant, Abundant, and Very Abundant; Low Prime - Slightly Abundant; Top Choice - Moderate and Modest; Low Choice - Small

[3] Degrees of doneness: Rare - 60°C, Medium - 71°C, and Well-done - 76°C

[4] SEM (largest) of the least square means.

Table 2.4 Least-squares means (n = 64 / degree of doneness) of the percentage of samples rated as acceptable[1] for each palatability trait evaluated by consumers for strip loin steaks across 4 marbling categories and 3 degrees of doneness.

Treatment	Juiciness acceptability	Tenderness acceptability	Flavor acceptability	Overall liking acceptability
Quality Grade[2]				
Super Prime	95.8^{a}	95.2^{a}	93.2^{a}	95.5^{a}
Low Prime	86.6^{b}	90.7^{ab}	84.4^{b}	87.5^{b}
Top Choice	84.8^{b}	86.8^{b}	86.1^{b}	85.1^{b}
Low Choice	81.3^{b}	85.3^{b}	84.2^{b}	84.7^{b}
SEM[4]	3.4	2.8	2.3	2.4
P-value	< 0.01	< 0.01	< 0.01	< 0.01
Degree of doneness[3]				
Rare	93.9^{a}	93.6^{a}	89.4	92.4^{a}
Medium	87.7^{b}	87.1^{b}	84.7	85.6^{b}
Well-done	80.9^{c}	89.0^{b}	88.2	88.8^{ab}
SEM[4]	2.4	1.9	1.8	1.9
P-value	< 0.01	< 0.01	0.10	< 0.01

[abc] Least squares means within the same section of the same column without a common superscript differ ($P < 0.05$).

[1] Percentage of samples rated acceptable for the palatability trait by consumer sensory panelists.

[2] Marbling scores: Super Prime - Moderately Abundant, Abundant, and Very Abundant; Low Prime - Slightly Abundant; Top Choice - Moderate and Modest; Low Choice - Small

[3] Degrees of doneness: Rare - 60°C, Medium - 71°C, and Well-done - 76°C

[4] SEM (largest) of the least square means.

Table 2.5 Least-squares means (n = 8 / panel) of trained sensory panelist palatability ratings[1] for strip loin steaks across 4 marbling categories and 3 degrees of doneness.

Treatment	Initial juiciness	Sustained juiciness	Myofibrillar tenderness	Connective tissue amount	Overall tenderness	Beef flavor intensity
Quality Grade[2]						
Super Prime	76.0^{a}	70.2^{a}	76.6^{a}	3.4^{b}	74.9^{a}	57.7^{a}
Low Prime	64.9^{b}	58.0^{b}	65.4^{b}	5.0^{a}	62.8^{b}	49.4^{b}
Top Choice	63.5^{bc}	56.6^{bc}	64.9^{b}	4.5^{a}	62.3^{b}	47.5^{b}
Low Choice	60.4^{c}	52.8^{c}	62.9^{b}	5.3^{a}	59.6^{b}	43.7^{c}
SEM[4]	1.5	1.6	1.3	0.3	1.5	1.4
P-value	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Degree of doneness[3]						
Rare	71.8^{a}	65.5^{a}	70.8^{a}	4.8	68.3^{a}	51.8
Medium	68.3^{a}	61.8^{b}	69.3^{a}	4.8	66.6^{a}	49.1
Well-done	58.6^{b}	51.0^{c}	62.2^{b}	4.0	59.8^{b}	47.9
SEM[4]	1.4	1.4	1.0	0.3	1.1	1.3
P-value	< 0.01	< 0.01	< 0.01	0.07	< 0.01	0.07

^{abc} Least squares means within the same section of the same column without a common superscript differ ($P < 0.05$).

[1]Sensory scores: 0 = extremely dry/tough/bland/none, 50 = neither juicy/dry/tough/tender, 100 = extremely juicy/tender/abundant/intense.

[2] Marbling scores: Super Prime - Moderately Abundant, Abundant, and Very Abundant; Low Prime - Slightly Abundant; Top Choice - Moderate and Modest; Low Choice - Small

[3] Degrees of doneness: Rare - 60°C, Medium - 71°C, and Well-done - 76°C

[2] SEM (largest) of the least square means.

Table 2.6 Least squares means for the interaction ($P < 0.05$) between quality[1] treatments and degree of doneness[2] for Warner-Bratzler shear force (WBSF), slice shear force (SSF), pressed juice percentage (PJP), and cook loss.

Degree of doneness/quality treatment	WBSF, kg	SSF, kg	PJP, %	Cook Loss, %
Rare				
Super Prime	2.1^{c}	12.7	23.5	15.6
Low Prime	2.5^{b}	13.6	21.1	14.6
Top Choice	2.6^{b}	13.5	21.9	15.6
Low Choice	2.9^{a}	15.0	21.7	14.4
SEM[3]	0.1	0.7	0.7	0.8
P-value	< 0.01	0.11	0.11	0.56
Medium				
Super Prime	2.0^{c}	11.5^{b}	20.3^{a}	20.0^{b}
Low Prime	2.7^{b}	13.4^{ab}	15.0^{b}	24.6^{a}
Top Choice	3.0^{a}	14.7^{a}	16.9^{b}	23.4^{a}
Low Choice	3.0^{a}	14.4^{a}	17.0^{b}	23.1^{a}
SEM[3]	0.1	0.7	0.7	0.8
P-value	< 0.01	< 0.01	< 0.01	< 0.01
Well-Done				
Super Prime	2.0^{c}	11.0^{c}	16.8^{a}	24.3^{b}
Low Prime	2.9^{b}	12.9^{b}	14.9^{ab}	26.2^{ab}
Top Choice	3.2^{a}	13.2^{b}	13.3^{b}	27.2^{a}
Low Choice	3.3^{a}	16.6^{a}	14.8^{ab}	25.3^{ab}
SEM[3]	0.1	0.7	0.7	0.8
P-value	< 0.01	< 0.01	< 0.01	0.05

[abc] Least squares means within the same section of the same column without a common superscript differ ($P < 0.05$).

[1] Marbling scores: Super Prime - Moderately Abundant, Abundant, and Very Abundant; Low Prime - Slightly Abundant; Top Choice - Moderate and Modest; Low Choice - Small

[2] Degrees of doneness: Rare - 60°C, Medium - 71°C, and Well-done - 76°C

[3] SEM (largest) of the least square means.

Table 2.7 Least squares means for fat, moisture, protein, and ash percentage across 4 marbling categories.

Quality Grade[1]	Fat %	Moisture %	Protein %	Ash %
Super Prime	13.7^{a}	64.2^{d}	20.2^{c}	3.7^{a}
Low Prime	9.7^{b}	67.2^{c}	22.6^{b}	3.6^{c}
Top Choice	5.8^{c}	69.8^{b}	23.0^{ab}	3.7^{ab}
Low Choice	4.0^{d}	71.2^{a}	23.4^{a}	3.6^{bc}
SEM[1]	0.6	0.4	0.3	0.02
P-Value	< 0.01	< 0.01	< 0. 01	< 0.01

[abc] Least squares means within the same column without a common superscript differ ($P < 0.05$).
[1] Marbling scores: Super Prime - Moderately Abundant, Abundant, and Very Abundant; Low Prime - Slightly Abundant; Top Choice - Moderate and Modest; Low Choice - Small
[2] SEM (largest) of the least square means.

References

American Meat Science Association. 2016. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. 2 ed. American Meat Science Association, Champaign, IL.

AMSA. 2016. Research guidelines for cookery, sensory evaluation, and instrumental tenderness measurements of meat. 1.02 ed. American Meat Science Association, Champaign, IL.

Beyer, E. S., K. M. Harr, B. A. Olson, E. A. Rice, C. K. Jones, M. D. Chao, J. L. Vipham, M. D. Zumbaugh, and T. G. O'Quinn. 2021. Palatability traits of sirloin cap steaks from four USDA quality grades. Meat and Muscle Biology 5:1-10. doi:10.22175/mmb.12424

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. https://ttu-ir.tdl.org/ttu-ir/handle/2346/73425

Cashman, D. A., L. D. Woolley, T. G. O'Quinn, J. F. Legako, J. C. Brooks, and M. F. Miller. 2015. Consumer assessment of beef strip steaks of varying marbling and enhancement levels cooked to three degrees of doneness. Meat science 101:104. doi:http://dx.doi.org/10.1016/j.meatsci.2014.09.018

Corbin, C., T. O'Quinn, A. Garmyn, J. Legako, M. Hunt, T. Dinh, R. Rathmann, J. Brooks, and M. Miller. 2015a. Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments. Meat science 100:24-31.

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. 2015b. Sensory evaluation of tender beef strip loin steaks of varying marbling levels and quality treatments. Meat science 100:24-31. doi:10.1016/j.meatsci.2014.09.009

Cox, R. J., J. M. Thompson, C. M. Cunial, S. Winter, and A. J. Gordon. 1997. The effect of degree of doneness of beef steaks on consumer acceptability of meals in restaurants. Meat science 45:75-85. doi:10.1016/S0309-1740(96)00080-0

Decker, L. K., E. S. Beyer, M. D. Chao, M. D. Zumbaugh, J. L. Vipham, and T. G. O'Quinn. 2024a. Effects of thawing method on palatability traits, quality attributes, and thawing characteristics of beef steaks. Meat and Muscle Biology 8:1-17. doi:10.22175/mmb.17687

Decker, L. K., E. S. Beyer, M. D. Chao, M. D. Zumbaugh, J. L. Vipham, and Travis G. O’Quinn. 2024b. Effects of Thawing Method on Palatability Traits, Quality Attributes, and Thawing Characteristics of Beef Steaks. Meat and Muscle Biology 8.

Drey, L. N., L. L. Prill, B. A. Olson, E. A. Rice, J. M. Gonzalez, J. L. Vipham, T. A. Houser, E. A. E. Boyle, and T. G. O’Quinn. 2019. Evaluation of marbling and enhancement’s abilities to compensate for reduced beef palatability at elevated degrees of doneness. Journal of Animal Science 97:669-686. doi:10.1093/jas/sky435

Emerson, M. R., D. R. Woerner, K. E. Belk, and J. D. Tatum. 2013. Effectiveness of USDA instrument-based marbling measurements for categorizing beef carcasses according to differences in longissimus muscle sensory attributes. Journal of Animal Science 91:1024-1034. doi:10.2527/jas.2012-5514

Farmer, K. J. 2022. Evaluation of the impact of bone-in versus boneless cuts on beef palatability. Master's Thesis, Kansas State University, Manhattan, KS. https://krex.k-state.edu/dspace/handle/2097/42052

Farmer, K. J., E. S. Beyer, S. G. Davis, K. M. Harr, K. R. Lybarger, L. A. Egger, M. D. Chao, J. L. Vipham, M. D. Zumbaugh, and T. G. O'Quinn. 2022. Evaluation of the impact of bone-in versus boneless cuts on beef palatability. Meat and Muscle Biology 6:1-13. doi:10.22175/mmb.15488

Legako, J., J. Brooks, T. G. O'Quinn, T. Hagan, R. Polkinghorne, L. Farmer, and M. Miller. 2015a. Consumer palatability scores and volatile beef flavor compounds of five USDA quality grades and four muscles. Meat science 100:291-300.

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

Lorenzen, C., T. Neely, R. Miller, J. Tatum, J. Wise, J. Taylor, M. Buyck, J. Reagan, and J. Savell. 1999a. Beef customer satisfaction: Cooking method and degree of doneness effects on the top loin steak. Journal of Animal Science 77:637-644. doi:10.2527/1999.773637x

Lorenzen, C. L., V. K. Davuluri, K. Adhikari, and I. U. Grün. 2005. Effect of end-point temperature and degree of doneness on sensory and instrumental flavor profile of beef steaks. Journal of food science 70:S113-S118. doi:10.1111/j.1365-2621.2005.tb07114.x

Lorenzen, C. L., R. K. Miller, J. F. Taylor, T. R. Neely, J. D. Tatum, J. W. Wise, M. J. Buyck, J. O. Reagan, and J. W. Savell. 2003. Beef customer satisfaction: Trained sensory panel ratings and Warner-Bratzler shear force values. Journal of Animal Science 81:143-149. doi:10.2527/2003.811143x

Lorenzen, C. L., T. R. Neely, R. K. Miller, J. D. Tatum, J. W. Wise, J. F. Taylor, M. J. Buyck, J. O. Reagan, and J. W. Savell. 1999b. Beef customer satisfaction: cooking method and degree of doneness effects on the top loin steak. Journal of Animal Science 77:637-644. doi:10.2527/1999.773637x

Lucherk, L., T. O'Quinn, J. Legako, R. Rathmann, J. Brooks, and M. Miller. 2016a. Consumer and trained panel evaluation of beef strip steaks of varying marbling and enhancement levels cooked to three degrees of doneness. Meat science 122:145-154.

Lucherk, L., T. O'Quinn, J. Legako, R. Rathmann, J. Brooks, and M. Miller. 2017. Assessment of objective measures of beef steak juiciness and their relationships to sensory panel juiciness ratings. Journal of animal science 95:2421-2437.

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

Lucherk, L. W., T. G. O'Quinn, J. F. Legako, S. D. Shackelford, J. C. Brooks, and M. Miller. 2022. Palatability of New Zealand grass-finished and American grain-finished beef strip steaks of varying USDA quality grades and wet-aging treatments. Meat and Muscle Biology 6:1-15. doi:10.22175/mmb.12601

Martinez, H. A., A. N. Arnold, J. C. Brooks, C. C. Carr, K. B. Gehring, D. B. Griffin, D. S. Hale, G. G. Mafi, D. D. Johnson, C. L. Lorenzen, R. J. Maddock, R. K. Miller, D. L. VanOverbeke, B. E. Wasser, and J. W. Savell. 2017. National Beef Tenderness Survey–2015: Palatability and shear force assessments of retail and foodservice beef. Meat and Muscle Biology 1:138-148. doi:10.22175/mmb2017.05.0028

McKenna, D. R., C. L. Lorenzen, K. D. Pollok, W. W. Morgan, W. L. Mies, J. J. Harris, R. Murphy, M. McAdams, D. S. Hale, and J. W. Savell. 2004. Interrelationships of breed type, USDA quality grade, cooking method, and degree of doneness on consumer evaluations of beef in Dallas and San Antonio, Texas, USA. Meat science 66:399-406.

McKillip, K. V., A. K. Wilfong, J. M. Gonzalez, T. A. Houser, J. A. Unruh, E. A. Boyle, and T. G. O'Quinn. 2017. Sensory evaluation of enhanced beef strip loin steaks cooked to 3 degrees of doneness. Meat and Muscle Biology 1.

McKinzie, T. B., A. J. Garmyn, C. C. McKinzie, M. Koohmaraie, J. F. Legako, D. R. Woerner, and M. F. Miller. 2025. Identifying Premium-Quality Beef in the United States—A Comparison of Beef Palatability from Grain-Finished Young and Mature Beef Cattle with Varying Marbling Scores. Foods. doi:https://doi.org/10.3390/foods14040676

Milligan, S. D., M. F. Miller, C. N. Oats, and C. B. Ramsey. 1997. Calcium chloride injection and degree of doneness effects on the sensory characteristics of beef inside round roasts. Journal of Animal Science 75:668-672. doi:10.2527/1997.753668x

NCBA. 2008. Beef steak color guide. National Cattelmen's Beef Association, Centennial, CO.

North American Meat Institute. 2014. The meat buyer's guide. 8th ed. North American Meat Institute, Washington D.C.

Nyquist, K. M., T. G. O'Quinn, L. N. Drey, L. W. Lucherk, J. Brooks, M. F. Miller, and J. F. Legako. 2018. Palatability of beef chuck, loin, and round muscles from three USDA quality grades. Journal of animal science 96:4276-4292.

O'Quinn, T. G., J. C. Brooks, and M. F. Miller. 2015. Consumer assessment of beef tenderloin steaks from various USDA quality grades at 3 degrees of doneness. Journal of food science 80:S444-S449. doi:10.1111/1750-3841.12775

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. Journal of Animal Science 90:626-634. doi:10.2527/jas.2011-4282

O'Quinn, T. G., J. F. Legako, J. C. Brooks, and M. F. Miller. 2018. Evaluation of the contribution of tenderness, juiciness, and flavor to the overall consumer beef eating experience1. Translational Animal Science 2:26-36. doi:10.1093/tas/txx008

Olson, B. A., E. A. Rice, L. L. Prill, L. N. Drey, J. M. Gonzalez, J. L. Vipham, M. D. Chao, and T. G. O'Quinn. 2019. Evaluation of beef top sirloin steaks of four quality grades cooked to three degrees of doneness. Meat and Muscle Biology 3:399-410. doi:10.22175/mmb2019.07.0022

Parrish, F. C., Jr., D. G. Olson, B. E. Miner, and R. E. Rust. 1973. Effect of degree of marbling and internal temperature of doneness on beef rib steaks. Journal of Animal Science 37:430-434. doi:10.2527/jas1973.372430x

Prill, L. 2019. The role of beef degree of doneness on consumer visual and palatability perceptions. Department of Animal Sciences and Industry.

Prill, L. L., L. N. Drey, B. A. Olson, E. A. Rice, J. M. Gonzalez, J. L. Vipham, M. D. Chao, P. D. Bass, M. J. Colle, and T. G. O'Quinn. 2019a. Visual degree of doneness impacts beef palatability for consumers with different degree of doneness preferences. Meat and Muscle Biology 3:411-423. doi:10.22175/mmb2019.07.0024

Prill, L. L., L. N. Drey, E. A. Rice, B. A. Olson, J. M. Gonzalez, J. L. Vipham, M. D. Chao, P. D. Bass, M. J. Colle, and T. G. O'Quinn. 2019b. Do published cooking temperatures correspond with consumer and chef perceptions of steak degrees of doneness? Meat and Muscle Biology 3:510-525. doi:10.22175/mmb2019.09.0040

Sepulveda, C. A., Garmyn, A. J., Legako, J. F., Miller, M. F. 2019. Cooking Method and USDA Quality Grade Affect Consumer Palatability and Flavor in beef strip Loin Steaks. Meat and Muscle Biology. doi:https://doi.org/10.22175/mmb2019.07.0031

Shackelford, S., T. Wheeler, and M. Koohmaraie. 1999. Evaluation of slice shear force as an objective method of assessing beef longissimus tenderness. Journal of Animal Science 77:2693-2699.

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. National Academy Press, Washington, D.C. p 124-137.

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. 1985. Relationship of USDA marbling groups to palatability of cooked beef. Journal of Food Quality 7:289-308. doi:10.1111/j.1745-4557.1985.tb01061.x

Smith, G. C., J. W. Savell, H. R. Cross, Z. L. Carpenter, C. E. Murphey, G. W. Davis, H. C. Abraham, F. C. Parrish Jr, and B. W. Berry. 1987. Relationship of USDA quality grades to palatability of cooked beef. Journal of Food Quality 10:269-286. doi:10.1111/j.1745-4557.1987.tb00819.x

Tatum, J. D., G. C. Smith, B. W. Berry, C. E. Murphey, F. L. Williams, and Z. L. Carpenter. 1980. Carcass characteristics, time on feed and cooked beef palatability attributes. Journal of Animal Science 50:833-840.

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

Umberger, W. J., D. M. Feuz, C. R. Calkins, and K. M. Killinger. 2000. The value of beef flavor: Consumer willingness-to-pay for marbling in beef steaks. Western Agric. Econ. Assoc. Annu. Mtg. Vancouver, BC, Canada.

USDA. 2017. United States standards for grades of carcass beef. Untied States Department of Agriculture, Washington, DC.

USDA. 2025. Certified Beef Program Comparison (7/14/2025) - PDF Version. USDA - Agriculture Marketing Service.

USDA-AMS. 2024. Historical Beef Grading Data.

USDA-AMS. 2025a. Historical Cutout Data 2002-2025.

USDA-AMS. 2025b. May Grade Volume Report.

USDA-AMS. 2025c. USDA Beef Carcass Price Equivalent Index Value.

Vierck, K. R., J. M. Gonzalez, T. A. Houser, E. A. E. Boyle, and T. G. O'Quinn. 2018. Marbling texture's effects on beef palatability. Meat and Muscle Biology 2:127-138. doi:10.22175/mmb2017.10.0052

Vierck, K. R., K. V. McKillip, T. G. O'Quinn, and J. F. Legako. 2019. The impact of enhancement, degree of doneness, and USDA quality grade on beef flavor development. Meat and Muscle Biology 3:299-312. doi:10.22175/mmb2019.05.0014

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 ratings of beef strip loin steaks. Journal of Animal Science 94:4930-4942. doi:10.2527/jas.2016-0893

Williams, L. E. 2006. Consumer perceptions of branded beef products. Master's Thesis, University of Tennessee, Knoxville, TN.

Appendix A - Carcass data

Appendix Table 2.1 Average marbling scores, skeletal maturity, and lean maturity for carcasses across 4 marbling categories.

Quality Grade	Marbling Score	Skeletal Maturity	Lean Maturity
Super Prime[1]	918[a]	176	177[a]
Low Prime[2]	751[b]	169	169[b]
Top Choice[3]	593[c]	167	169[b]
Low Choice[4]	451[d]	172	173[ab]
SEM[5]	10.7	3.2	2.0
P-Value	< 0.01	0.23	0.02

[abc] Least squares means within the same section of the same column without a common superscript differ ($P < 0.05$).
[1]Marbling scores represented- 800 - 1100
[2]Marbling scores represented- 700 - 799
[3]Marbling scores represented- 500 - 699
[4]Marbling scores represented- 400 - 499
[5] SEM (largest) of the least square means.

Appendix B - Sensory Panel Evaluation Forms

Informed Consent Statement

1. I volunteer to participate in research involving Sensory Evaluation of Meat. This research will be conducted by personnel in the Department of Animal Sciences and Industry at Kansas State University.

2. I fully understand the purpose of the research is for the evaluation of beef steaks, pork chops, lamb chops, goat meat, poultry meat, ground meat, and processed meat products from the previously mentioned species for the sensory traits of tenderness, juiciness, flavor intensity, connective tissue amount, off flavor presence, odor, and color and sensory evaluation will last approximately one hour.

3. I understand that there are minimal risks associated with participating and that those risks are related to possible food allergies. All meat products will be USDA inspected and all ingredients are GRAS (generally accepted as safe) by FDA.

4. I understand that my performance as an individual will be treated as research data and will in no way be associated with me for other than identification purposes, thereby assuring confidentiality of my performance and responses.

5. My participation in this study is purely voluntary; I understand that my refusal to participate will involve no penalty or loss of benefits to which I am otherwise entitled and that I may discontinue participation at any time without penalty or loss of benefits to which I am otherwise entitled.

6. If I have any questions concerning my rights as a research subject, injuries or emergencies resulting from my participation, I understand that I can contact the Committee on Research Involving Human Subjects, 203 Fairchild Hall, Kansas State University, Manhattan, KS 66506, at (785) 532-3224.

7. If I have questions about the rationale or method of the study, I understand that I may contact, Dr. Travis O'Quinn, 247 Weber Hall, Kansas State University, Manhattan, KS 66506, at (785) 532-3469 or Sally Stroda, 107 Weber Hall, at 785-532-1273.

I have read the Subject Orientation and Test Procedure statement and signed this informed consent statement, this ________________________ day of _____________________, __________.

________________________________ ________________________________

Printed name Signature

Consumer Sensory Ballot

Panelist Number

Gender

Male

Female

Age

Under 20

20 to 29 years old

30 to 39 years old

40 to 49 years old

50 to 59 years old

over 60

Ethnic Origin

- African American
- Asian
- Caucasian/White
- Latino
- Native American
- Other
- Mixed Race

Marital Status

- Single
- Married

Household Size

- 1 person
- 2 People
- 3 People
- 4 People
- 5 People
- 6 People
- > 6 People

Annual Household Income

- < $25,000
- $25,000 - $34,999
- $35,000 - $49,999
- $50,000 - $74,999
- $75,000 - $99,999
- $100,000 - $149,999
- $150,000 - $199,999
- > $199,999

Highest Level of Education Completed

- Non-High School Graduate
- High School Graduate
- Some College / Technical School
- College Graduate
- Post-College Graduate

When eating beef, what palatability trait is the most important to you?

- Flavor
- Juiciness
- Tenderness

When consuming beef, which palatability trait do you experience the greatest amount of **variation** with?

- Flavor
- Juiciness
- Tenderness

When eating beef steaks, what degree of doneness do you prefer?

- Very Rare
- Rare
- Medium-Rare
- Medium
- Medium-Well
- Well-Done
- Very Well-Done

How many times a week do you consume beef?

0 3 6 9 12 15 18 21

None

Please indicate the importance of each trait when purchasing fresh beef steaks.

Animal Welfare

Extremely Unimportant 0 — Extremely Important 100

Antibiotic use in the animal.

Extremely Unimportant 0 — Extremely Important 100

Brand of Product

Extremely Unimportant 0 — Extremely Important 100

Eating Satisfaction Claims (ex: Guaranteed Tender)

Extremely Unimportant 0 — Extremely Important 100

Animal fed a corn-based diet

Extremely Unimportant 0 — Extremely Important 100

Animal fed a forage-based (grass) diet

Extremely Unimportant 0 — Extremely Important 100

Growth hormone use in the animal

Extremely Unimportant 0 — Extremely Important 100

Natural or Organic Claims

Extremely Unimportant 0 — Extremely Important 100

Nutrient Content

Extremely Unimportant 0 — Extremely Important 100

Familiarity with cut

Extremely Unimportant 0 — Extremely Important 100

Packaging Type

Extremely Unimportant 0 — Extremely Important 100

Price

Extremely Unimportant 0 — Extremely Important 100

Size, weight, and thickness

Extremely Unimportant 0 — Extremely Important 100

Color

Extremely Unimportant 0 — Extremely Important 100

USDA Grade

Extremely Unimportant 0 — Extremely Important 100

Marbling

Extremely Unimportant
0

Extremely Important
100

Fresh Never Frozen

Extremely Unimportant
0

Extremely Important
100

→

KANSAS STATE
UNIVERSITY

Sample Number

1095

Juiciness

Extremely Dry
0

Neither Juicy nor Dry
50

Extremely Juicy
100

Juiciness

Was the sample acceptable for juiciness?

Acceptable

Unacceptable

Tenderness

Extremely Tough	Neither Tough nor Tender	Extremely Tender
0	50	100

Tenderness

Was the sample acceptable for tenderness?

Acceptable

Unacceptable

Flavor

Dislike Extremely	Neither Like nor Dislike	Like Extremely
0	50	100

Flavor

Was the sample acceptable for flavor?

Acceptable

Unacceptable

Overall Liking

Dislike Extremely	Neither Like nor Dislike	Like Extremely
0	50	100

Overall

Was the sample acceptable overall?

Acceptable

Unacceptable

→

Trained Sensory Ballot

KANSAS STATE UNIVERSITY

Panelist

Date

Time

AM

PM

Warm Up

Initial Juiciness

Extremely Dry 0	Neither Dry nor Juicy 50	Extremely Juicy 100

.

Sustained Juiciness

Extremely Dry 0	Neither Dry nor Juicy 50	Extremely Juicy 100

.

Myofibrillar Tenderness

Extremely Tough 0	Neither Tough nor Tender 50	Extremely Tender 100

Connective Tissue Amount

None	Extremely Abundant
0	100

Overall Tenderness

Extremely Tough	Neither Tough nor Tender	Extremely Tender
0	50	100

.

Beef Flavor Intensity

Extremely Bland	Extremely Intense
0	100

Off Flavor Intensity

Extremely Bland	Extremely Intense
0	100

☐ Not Applicable

Off-Flavor Description

→