# Grading Predictions of Beef Palatability

## Introduction

Beef quality grading uses the marbling score assigned to the ribeye muscle of a carcass to predict palatability of the resulting beef products. Marbling is the white flecks of fat interspersed within the muscle and also can be referred to as intramuscular fat. The U.S. Department of Agriculture (USDA) formulated and publicized the standards for grades of carcass beef in 1926 that have been used throughout the nation and evolved over the years to be known as the Standards for Grades of Slaughter Cattle and Standards for Grades of Carcass Beef (USDA, 1996). Although the U.S. Standards for Grades of Carcass Beef have been revised or amended 12 times since their adoption in 1926, the basic elements of the original beef quality grades (i.e., assessments of physiological maturity and amount of marbling) remain in use today (USDA, 1997).

The USDA-Agricultural Marketing Service (AMS) approved the usage of camera-assisted quality grading in 2006. This technology is being utilized in several U.S. beef plants, allowing for increased objectivity and consistency in the beef grading process, as well as definitive breaks between each quality grade. Many researchers have shown that USDA Quality Grades applied by trained USDA official graders truly demonstrate palatability differences. Recently, when evaluating a camera-assisted quality-grading system, researchers also found that camera measurements of quality grade demonstrate the palatability differences amongst quality grades with increased precision and greater correlation of marbling and sensory attributes versus traditional grading (Emerson et al., 2011).

## Quality Grades

The eight USDA Quality Grades for beef include: USDA Prime, Choice, Select, Standard, Commercial, Utility, Cutter, and Canner. The first four quality grades are reserved for carcasses of young cattle less than 42 months of age (A and B-maturity); while the latter four quality grades are used for carcasses of cattle over 42 months of age (C, D, and E-maturity, also known as Hardbone carcasses).

**Table 1. Relationship Between Marbling, Maturity and Carcass Quality Grade[1]**

| Degrees of Marbling | Maturity[2] | | | | |
|---|---|---|---|---|---|
| | A[3] | B | C | D | E |
| Slightly Abundant | PRIME | | | | |
| Moderate | | | COMMERCIAL | COMMERCIAL | |
| Modest | CHOICE | | | | |
| Small | | | | | |
| Slight | SELECT | | UTILITY | UTILITY | |
| Traces | | | | | |
| Practically Devoid | STANDARD | | | CUTTER | |

[1]Assumes that firmness of lean is comparably developed with the degrees of marbling and that the carcass is not a "dark cutter."
[2]Maturity increases from left to right (A through E).
[3]The A-maturity portion of the Figure is the only portion applicable to bullock carcasses.



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In application, A and B-maturity carcasses are graded using the quality grades designated for young beef, while C, D, and E-maturity are simply considered "no roll" or un-graded carcasses. Other carcasses that would be classified as "no roll" could include dark cutting USDA Select carcasses, B-maturity beef carcasses with Slight (USDA Select) marbling, carcasses exhibiting blood splash in the ribeye muscle, beef carcasses with calloused ribeyes, in addition to those with excessive physiological maturity (C, D and E-Maturity).

Physiological maturity is used to indicate age, and is determined by evaluating the color of the lean in the ribeye as well as the amount of ossification in the vertebral column. Physiological age can be determined on the harvest floor using dentition. Dentition is performed on all cattle harvested under USDA inspection and is used to determine cattle greater than 30 months of age. When cattle are identified as being greater than 30 months, their carcasses are segregated from the rest of the population and are fabricated entirely into boneless retail cuts. An in depth look at beef quality grading can be found on www.beefresearch.org in the Fact Sheets & White Papers section under Product Enhancement Research.

## Snapshot of current U.S. beef supply

The quality of the U.S. beef supply has gradually changed throughout the years and quality grades have steadily improved over the last two decades. There was a drastic decrease in the amount of USDA Prime and Choice carcasses available from 1974 (74%) to 1991 (55%; Smith et al., 1992). Since the introduction of National Beef Quality Audits (NBQA) in 1991, which are performed every five years as a snapshot of the beef industry and an evaluation of progress made, the percent of USDA Prime and Choice carcasses decreased again in 1995 (49%) but has steadily increased in every audit since and was reported in the latest 2011 NBQA at an all-time high of 61% (Moore et al., 2012). The percent of each quality grade from cattle graded in the United States over the last 15 years were: USDA Prime (3.2%), USDA Choice (59.8%), USDA Select (36.7%), and USDA Standard (0.3%; USDA, 2011). According to instrument grading data collected in the 2011 NBQA, when evaluating the amount of USDA Choice cattle by month, January 2011 (64.9%) and March 2011 (64.7%) were the months with the greatest percentage of USDA Choice cattle; whereas November 2010 (58.3%) and November 2011 (57.7%) were the months with the lowest percentage of USDA Choice grading cattle (Gray et al., 2012). Data from the 2011 NBQA revealed that the U.S. beef supply consisted of 2.0% Prime, 20.3% premium Choice, 36.6% low Choice, 31.6% Select, 4.1% Standard, 3.2% Dark Cutters, 1.0% Hardbone, and 1.1% Over 30 Months (Moore et al., 2012).

Beef industry leaders gathered in April 2012 during the Strategy Workshop of the NBQA agreed that the "ideal consist of quality grades" goal for the next five years should be 5.0% Prime, 31.0% premium Choice, 33.0% low Choice, 31.0% Select, and 0.0% Standard, Dark Cutter, Hardbone, and Over 30 Months. Export markets such as Asia represent huge demand for USDA Prime beef products; thus, a majority of USDA Prime beef is exported and what is not sold to foreign markets is typically sold to high-end Prime steakhouses. Premium Choice and low Choice product is often found in steakhouses and higherend foodservice establishments, while a smaller portion is sold to consumers through retail. Retailers typically are the large purchaser of USDA Select product, but do carry some branded beef products and USDA Choice and premium Choice selections. Family-style restaurants also purchase USDA Select product to serve to their customers who place greater emphasis on quantity and price over quality. Lastly, quick service restaurants are large buyers of "no roll" beef to provide customers with beef options at the most economical price. These products are typically paired with sauces or further processed and thinly sliced into roast beef sandwiches served as Philly cheesesteak, etc. The variation in quality of these products is more acceptable when using these preparation methods and in these markets.

## Palatability

Studies conducted over the past several decades to quantify marbling's contribution to differences in eating quality of beef generally have established low-to moderate positive relationships between marbling and cooked beef tenderness, juiciness, and flavor (Briskey and Bray, 1964; Jeremiah et al., 1970; Smith et al., 1987). Smith et al. (1987) reported positive relationships between marbling and beef palatability characteristics among *longissimus dorsi* steaks from A-maturity carcasses. In this study, differences in marbling (ranging from Practically Devoid to Moderately Abundant) explained 22, 28, 30, and 36% of the variation in sensory panel ratings for juiciness, tenderness, flavor, and overall palatability, respectively.

### Flavor

Beef flavor is an extremely complex attribute with a wide variety of influences, subjectivity, and varying descriptive terms. Many components responsible for meat flavor have not yet been identified; however, recent research has initiated an in-depth look at multiple factors that can be associated with beef flavor. In addition, meat flavor and aroma are very difficult to separate because flavor stimulates the senses on the tongue and aroma stimulates the nerve endings in the nasal passage. Together, flavor and aroma constitute an important characteristic of beef that affects the overall palatability of the product. Smith et al. (1987) showed that steaks derived from A-maturity cattle exhibited a direct, linear relationship between the amount of marbling and flavor ratings of trained sensory panelists. McBee and Wiles (1967) also found that flavor increased in a direct, linear relationship with additional degrees of marbling.

### Juiciness

Juiciness and tenderness are closely related, and it is often noted that the more tender the meat, the more readily juices are emitted, and the "juicier" the meat is perceived. Juiciness of meat varies with every cut and can play a vital role in the palatability of beef to consumers. Juices contain many important flavor components and assist in fragmenting and softening meat during chewing (Aberle et al., 2001). Without juiciness, the acceptability of beef is extremely limited, and the palatability profile is destroyed. Juiciness in meat is attributed to water and melted lipids that are released upon chewing. Aberle et al. (2001) refers to the water and melted lipids as a broth which may stimulate flow of saliva and thus improve apparent juiciness. It also has been documented that differences in pH, water-holding capacity, fatness, and firmness were directly related to the juiciness of cooked meat products (Lawrie, 1966). Marbling not only reduces the cook-loss percentage, but also increases the juiciness by retaining the juices inside beef cuts.

### Tenderness

Tenderness is the single most researched palatability characteristic because there are so many different factors that can affect tenderness both positively and negatively. Aberle et al. (2001) stated that the sensation of tenderness has several components of varying importance, and perception of tenderness by humans is very difficult to duplicate by scientific instrumentation. Bratzler (1971) and Smith (1972) both concluded that tenderness is the single most important attribute in distinguishing beef palatability and acceptability.

Tenderness appears to be sought after above all other quality attributes by the consumer; however, the term also is the most difficult to define (Lawrie, 1966). Intramuscular lipids have been credited by meat industry personnel with making meat more tender (Aberle et al., 2001). Intramuscular fat also provides an insurance that protects the palatability of meat from adverse cooking situations such as rapid cooking, the wrong cookery method, or advanced degrees of doneness. It is known that fat does not conduct heat as readily as lean tissue sources; thus, it is likely highly marbled meat is more capable of withstanding higher temperatures without overcooking than



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meat containing less intramuscular fat. Although previous research suggests that degree of marbling is associated with the likelihood a steak will be tender (Smith et al., 1987), little is known about the exact role intramuscular fat deposition plays in cooked meat tenderness.

The lubrication theory suggests that marbling can act as a lubricant and ease the chewing process to enhance the perceived tenderness of the beef product. Savell and Cross (1988) stated that the "window of acceptability" for beef palatability ranges from the lower end of USDA Select through USDA Choice, thus some marbling is necessary to ensure acceptable palatability. Carpenter (1962) proposed that the lubricating properties of fat confound the sensation of tenderness. The bite theory suggests that since fat is less dense and less resistant to shear force than coagulated protein, the increase of marbling in a given meat sample decreases bulk density (Smith et al., 1973). The strain theory proposes that connective tissue may effectively be decreased in strength and insolubility by intramuscular fat deposits. Intramuscular fat also may loosen the structure of connective tissue fibers enough to aid in heat penetration and thus increase the solubility of the connective tissue (Carpenter, 1962).

## Instrument Grading

United States beef quality grades continued to be based on subjective visual assessments of marbling until 2006 when two camera-based grading systems, designed to objectively quantify marbling, were approved for use in determining official USDA marbling scores (Woerner and Belk, 2008). By utilizing instruments to aid in the grading of beef carcasses, the USDA aimed to increase accuracy as well as uniformity of grade application within the industry (USDA, 2009). The technology endured a strenuous two-phase testing procedure that required the camera-grading instruments to (1) accurately predict "gold standard" marbling scores (estimated to the nearest 10 marbling units) and (2) conduct the task at current processing-plant chain (throughput) speed. The "gold standard" mentioned above was a "mean expertpanel marbling score" determined by five USDA-AMS grading experts who calculated marbling scores on 4,000 individual carcasses exhibiting the full range of marbling scores. Additional testing in commercial facilities also was used to evaluate the camera-based quality-grading system compared to the USDA official graders. More information about instrument grading can be found on www.beefresearch.org. Find The History of Instrument Grading of Beef in the Executive Summaries section under Product Enhancement Research.

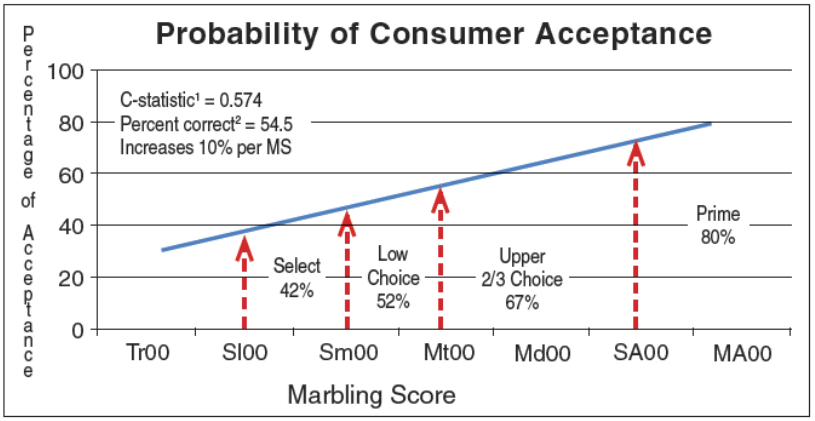


**Figure 2. Predicted probability of overall consumer acceptance of steaks by mean marbling score (Adapted from Platter et al., 2003)**

[1] The C-statistic is the area under the receiver operating characteristic curve.

[2] Percentage correct is the percentage of observations in the dataset correctly classified by the logistic regression equation.

[3] Quality grades evaluated from least to most amount of marbling: Traces ($TR^{00}$), Slight ($SL^{00}$), Small ($SM^{00}$), Modest ($MT^{00}$), Moderate ($MD^{00}$), Slightly Abundant ($SA^{00}$), and Moderately Abundant ($MA^{00}$).



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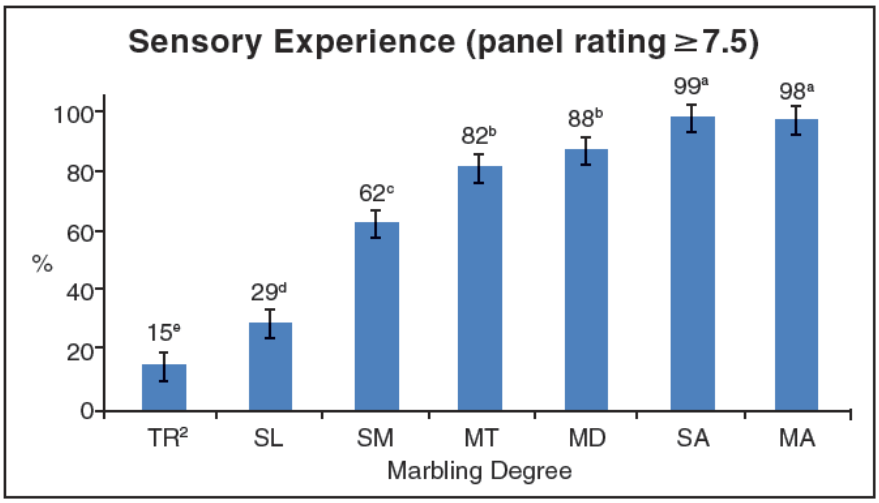


**Figure 1. Frequency of steaks representing each marbling degree receiving overall sensory experience[1] ratings ≥ 7.5 (Adapted from Emerson et al., 2011)**

[1] Scored using 15-cm unstructured line scale: 0 = minimal level of performance, 15 = maximal level of performance. Steaks with overall sensory experience ratings ≥ 7.5 delivered a "positive" sensory experience.

[2] Quality grades evaluated from least to most amount of marbling: Traces (TR), Slight (SL), Small (SM), Modest (MT), Moderate (MD), Slightly Abundant (SA), and Moderately Abundant (MA).

[abc,de] For each quality grade, means that do not share a common superscript letter differ ($P < 0.05$).

### Relationship of Marbling Scores to Palatability

USDA Quality Grades are used to predict the palatability of the meat from a beef carcass and that relationship has been documented both using USDA official grader visual estimates of marbling as well as instrumental measures of quality grades. When using highly trained USDA official graders providing visual estimates of marbling grades, trained sensory panelists found that in A and B-maturity groups, loins from Prime carcasses were more tender, flavorful and had a greater overall palatability rating than did Choice, Choice more than Good (currently recognized as USDA Select), and Good more than Standard (Smith et al., 1987). Since the 2006 introduction of instrument grading, similar research has been conducted using the camera-based system to evaluate marbling scores versus a highly trained group of USDA official graders.

When evaluating a camera-assisted quality-grading system, researchers found camera measurements of quality grade demonstrate the palatability differences among quality grades with increased precision and greater correlation of marbling and sensory attributes versus traditional grading (Emerson et al., 2011). Findings from this recent research revealed that the increased degree of marbling resulted in steaks having greater juiciness, tenderness, meaty/brothy flavor intensity, and buttery/beef fat flavor intensity (Emerson et al., 2011). Like Smith et al., the results showed that the likelihood of a steak delivering a positive eating experience became greater as the degree of marbling increased: Prime > Upper 2/3 Choice > Low Choice > Select > Standard (Figure 1; Emerson et al., 2011). Emerson et al. (2011) showed that camera marbling score explained 45, 40, 32, 71, and 61% of the variation in panel ratings for juiciness, tenderness, meaty/brothy flavor intensity, buttery/beef fat flavor intensity, and overall sensory experience, respectively. Camera marbling score, used as a single predictor, correctly classified 83.6% of the steaks in the experimental sample, with respect to their likelihood of delivering a positive sensory experience (Emerson et al., 2011). Similar results from Platter et al. (2003) demonstrated the probability that overall consumer acceptance of steaks increased approximately 10% for each full marbling score or quality grade (Figure 2, page 4). The data from

Figure 2 suggested that a marbling score of Modest[50] or higher was required to produce favorable odds that consumers would be willing to purchase steaks in the experimental auction (Platter et al., 2003). Platter et al. (2005) evaluated consumers' willingness to pay for beef strip loin steaks using an auction bidding method for differing degrees of marbling and found similar results, as the consumers' willingness to submit a bid increased as marbling score increased.



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Platter et al. (2005) also noted that marbling score alone accounted for only 3% of the observed variation in average bid price for steaks; however, by improving product quality and tenderness, consumers' willingness to purchase and the price they would pay for beef increased.

## Conclusions

Beef carcasses are sorted into homogeneous groups using USDA Quality Grades as a predictor of eating quality. Research shows that USDA Quality Grades effectively assess palatability differences when evaluated either by trained USDA official graders or by camera-based instrument measurements. The implementation of camera-based technology to objectively assist in the assignment of quality grades demonstrates an increased precision and accuracy in grade application, as well as a greater correlation of marbling scores and sensory attributes. Palatability is not based only on one characteristic but is based on the relationship of three characteristics - tenderness, juiciness, and flavor – and how they work or do not work together to determine beef eating satisfaction.

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