

Review of Instrument Augmented Assessment of USDA Beef Carcass Quality Grades

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INTRODUCTION

Assessment of marbling score (MS) at the 12th-rib interface of beef carcasses has long been the major determining value of carcasses and their cuts. Determination of MS is subjective, and besides for training from USDA, the only tool available to aid in the assessment of MS are marbling photographs illustrating the lower limits of marbling degrees. The tremendous variation and range in MS presented to graders and the human's visual assessment of MS can result in discrepancies (Cross, et al. 1980, 1984). Hueth et al. (2007) determined that there is a plant-to-plant bias assessing yield grades, as well as noting that graders are more consistent and accurate when grading lower quality carcasses. Therefore, all segments of the industry wish to utilize instruments that can assess MS and yield grade accurately and consistently.

In June 2006, two instruments for marbling assessment were approved for use by USDA. Nevertheless, industry was reluctant to implement use of instrument-augmented quality grading because of the perceived or real divergence that existed between instrument MS and USDA field grader MS. Thus, USDA began to investigate the divergence and made recommendations to adjust instruments to be more similar to field grader assessments. In 2009, after extensive data collection and adjustments to cameras, two cameras were approved for use in two different packing plant locations, and since then, several companies began utilization of instruments to augment quality grade assessments by USDA field graders.

An audit report was published by the USDA Office of the Inspector General (OIG Audit Report 50601-0002-31,

2013) that stated the USDA-Agricultural Marketing Service (AMS) needs to more effectively utilize its camera-based grading system and made several recommendations to AMS. The first recommendation was to form an ad hoc committee of independent and objective third party experts. Thus, AMS requested that the American Meat Science Association (AMSA) form a committee to address recommendations of OIG and respond to their audit findings. The audit also states camera grading is feasible and offers AMS flexibility in staffing needs but maintains cameras must provide consistent, accurate grades, and the system must be transparent to the public.

OBJECTIVE

The objective of this review is to publish major milestones of automated grading systems for USDA Quality Grading. In response to an official audit conducted by the USDA Office of the Inspector General (OIG), this review will outline the AMS Grading and Standardization branch's findings and responses to questions posed by OIG on the appropriateness and implementation of instrument grading in the U.S. Beef Industry. The review will investigate the thought process and summarize studies conducted by USDA to arrive at current automated grading procedures. The review will evaluate instrument performance, grader performance, and appropriateness of current standards. Finally, the review will provide recommendations to USDA-AMS to effectively manage and review instrument grading.

HISTORY OF BEEF GRADING

Beef grading, segregating cattle and beef carcasses based on expected value, began almost 90 y ago in the U.S. because cattle producers, buyers, and packers saw the need for a system to determine value of cattle to more accurately merchandize cattle and beef, as well as report market trends (Briskey and Bray, 1964). The need for a grading system became evident because of the tremendous variation in the cattle population and beef at that time. Thus, the USDA initiated work in 1916 to develop standards for grading livestock and meat (Briskey and Bray, 1964). In January, 1923, the USDA began grading

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beef carcasses using tentative U.S. standards. On June 3, 1926, the USDA pronounced these beef grade standards as the official U.S. Standards for Market Classes and Grades of Carcass Beef to become effective July 1, 1926. However, even with the official grade standards in place, much opposition was encountered. Packers were not convinced that this system would work; thus, they developed their own grading systems, whereas producers promoted stamping of carcasses based on the standards approved by the USDA. Conferences between packers, producers, and government officials in the late 1930s, resulted in the development of a single grading system (Briskey and Bray, 1964). Throughout the years, several revisions and changes have been made to the grading standards primarily because beginning grading standards were based on opinions. However, as universities began animal science programs, research was conducted to evaluate the grading standards and document the need for change. Also, as the cattle industry changed and progressed, periodically a need to revise the grading standards became evident. Some of the changes that have been made to the grading standards since their promulgation are: (1) the addition of the Standard grade in 1956, (2) lowering the marbling requirements for the Prime and Choice grades in 1965, (3) developing yield grading standards in 1965, (4) eliminating conformation score from the grading standards in 1975, (5) changing the Good grade to Select in 1987 (USDA, 1989), and (6) eliminating B maturity carcasses with “Small” or “Slight” marbling scores from the Choice and Select grades (USDA, 1997).

MAJOR MILESTONES OF INSTRUMENT AUGMENTED GRADING

Technology to improve the accuracy and uniformity of U.S. beef grading has been evident to producers, packers, and retailers for some time, and even to U.S. Congress for over 30 y since the U.S. General Accounting Office reported the need for improvement (Comptroller General of the United States, 1978). An outstanding historical review of instrument assessment of beef carcass yield and quality was presented by Woerner and Belk (2008). The beef industry has long sought objective methods to measure yield and quality factors of beef carcasses and cuts, as a prediction of cutability (red meat yield) and/or palatability (specifically tenderness). In 1979, NASA’s Office of Technology along with FSQS (Food Safety and Quality Service; currently AMS and FSIS – Food Safety Inspection Service) funded a project that identified two technologies, ultrasound and video image analysis, that could potentially be utilized to assess yield and quality of beef carcasses. Cross and Whitaker (1992) provide an excellent review of research conducted from 1980 – 1990, and the importance of instrument grading in value-based marketing systems. In 1990, the National Cattlemen’s Association formed an Instrument Grading Subcommittee to develop request for proposals for instrument grading (Cross and Whitaker, 1992).

The current review will focus on automated grading systems efficacy for application of USDA Quality Grades (QG). Table 1 presents a chronological summary of instrument grading approval dates by USDA, including ribeye area, yield grade, and marbling assessment. Instrument grading initiatives are based on the premise that grading accuracy, precision, and consistency benefits all segments of the beef industry – production to consumption. Thus by increasing accuracy, precision, and consistency, carcasses would more likely be classified correctly into their respective QG. An instrument to assess MS of beef carcasses would reduce the variation that has long existed between graders, shifts, and plants.

Early studies showed very little promise in utilization of instruments to predict MS, as expert MS and instrument assessments of MS showed little association (Woerner and Belk, 2008). Field graders across the country have been shown to lack accuracy and consistency when assigning official USDA QG (Ockerman and Cahill, 1969; Cross et al., 1984; Yates, 2013). Cross et al. (1984) reported the national percentage error for QG was 7.3% and stated that inaccuracies can negatively impact the integrity of the grading service and marketing of beef. Additionally, Smith et al. (2006) identified the need for implementation of instrument grading as a key message from the 2005 National Beef Quality Audit.

Video image analysis (VIA) has proven to be a viable objective measure of carcass cutability traits and was approved by USDA for assessment of LM area (USDA,

Table 1. USDA MRP AMS Livestock, Poultry and Seed Program Instrument Grading Chronological Summary

Factor/Grade	Date
Ribeye Area	February 2001
Instrument first approved	February 2001
Official Use	August 2001
USDA Yield Grade	March 2005
Instrument first approved	June 2005
Official Use	March 2007
ADDENDUM A - Fat Thickness - March 2007	
Instrument first approved	March 2007
Marbling Score	June 2007
Instrument first approved	November 2006
Grade Line Divergence Investigation	
Study 1: Instrument Data Review	September 2007
Study 2: Image Review	November 2007
Grade Line Review with Industry	November 2007
Grade line Alignment with Grader Input	
Instrument Data Review	September 2008
Image Review	November 2008
Grade Line Review with Industry	February 2009
Official Use of Instrument Grading	September 2009

2003) and officially assigning USDA Yield Grades (USDA, 2005). Moore et al. (2006, 2010) outlined methods to assess VIA instruments ability to evaluate MS both accurately and precisely at commercial processing facility production speeds. Performance requirements for instrument marbling evaluation (PRIME I; USDA, 2006a) were developed utilizing information from Moore et al. 2006. The instrument approval process described in PRIME I is a two phase approach: Phase I: demonstration of the repeatability of marbling score prediction on stationary beef carcasses, and Phase II: demonstration of the accuracy and precision of marbling score prediction at line speeds. Supervisors of USDA served as the “gold standard” for evaluation of MS during the approval process.

In June 2006, CVS (Computer Vision System; RMS Research Management Systems, USA, Inc., Fort Collins, CO) and VBG2000 (E+V Technology, Oranienburg, Germany) met the rigorous performance requirements of PRIME I to assess MS. The instruments incorporate several variables including the amount, size, and distribution of fat (marbling) present within the exposed ribeye, as well as variables of lean and fat color. Once approved through PRIME I by USDA-AMS LPS Program (USDA Agriculture Marketing Service Livestock, Poultry and Seed Program), companies and technology providers must obtain approval through (PRIME II; USDA, 2006b). Individual establishments utilizing instruments to assess MS for beef carcasses must conform to the operational procedures outlined in PRIME II. Specifically, PRIME II states: demonstration of a documented-program, in-plant procedures and verifications that ensure accurate and precise determinations are made by properly calibrated and verified instruments (USDA, 2006b). The approval process utilizes thousands of carcasses at multiple locations in assessing the predictive accuracy of an instrument and ensuring the functionality of the technology relative to the U.S. beef carcass population.

With PRIME I approval of instruments, USDA realized the tremendous need that the transition from human grading to instrument augmented grading be seamless and transparent to all parties; those parties include beef producers to end-product users. A smooth transition from human to instrument grading was extremely important to beef producers who look for livestock prices to be commensurate with quality and quantity through USDA grade metrics. In addition, producers utilize data generated from USDA grading information to make cattle selection decisions and herd improvements. These data are used in many expected progeny differences (EPDs), which can result in increased or decreased value of seed-stock. Not to mention, producers and packers also use value-based pricing grids that include USDA grades to determine value of individual beef carcasses. Certification programs could be impacted from this transition as well because of increases or decreases of product to programs. Just as important, retailers and restaurateurs, and in particular their customers, need to have confidence the grading system is providing the same quality products it has for almost 90 y.

Current acceptance of beef in U.S. and export markets is founded on quality expectations resulting from subjective grading and certification programs administered by AMS. However, as a transition to instrument grading was being considered and instrument approval process (PRIME I) completed, a divergence was exposed between USDA applied field grades and the equivalent instrument grades.

This divergence, as noted by packers, would drastically reduce the number of carcasses grading USDA Prime and Choice. Thus, packers were hesitant to seek PRIME II approval due to significant monetary losses to producers and packers with reduced grading performance. Therefore, a Foundation Trial was conducted by USDA to examine the causes of the divergence and provide options for implementing augmented instrument grading for determination of USDA QG.

FOUNDATION TRIAL

Phase I

The objective of Phase I of this trial was to quantify any divergence between USDA field graders and instrument quality grades among nine plants. These plants represented three companies, all with multiple shifts and multiple USDA graders during each shift. All plants utilized only E+V instruments. This study utilized instrument assessed MS (a measure of marbling and thus quality grade; instrument QG) and field-assessed USDA quality grades (grader QG) of 1.22 million carcasses over a four week period, which represented approximately ½ of the total national beef slaughter under Federal inspection for that four-week period.

Data were collected, pooled and partitioned into a MS × USDA quality-grade matrix by E+V Technology GmbH (E+V), the technology provider for the nine plants. The data matrix was analyzed independently by E+V and USDA. Data were analyzed to ascertain the magnitude of any divergence for the critical marbling lines for the Choice (MS = 395) and Prime (MS = 695) grades by comparing the relationship between USDA field grades and instrument output.

For the purpose of this study, it was deemed more important that USDA field graders be unaware that data were being collected rather than synchronize their performance to corresponding instrument images. If the divergence was in a large part due to USDA field graders, it was quite important to prevent them from realizing they were being observed. It is possible that graders perform differently in the absence or presence of supervisors or review teams. This possible Hawthorne effect (i.e., a change in grading occurring because graders realize they are being observed) would skew data collection. The Hawthorne effect has been studied by researchers and is defined as a temporary change to behavior or performance in response to a change in environmental conditions or any new or increased attention (Newstrom and Davis, 2002). Many academicians and industry carcass grading supervisors

have observed this change in USDA field graders during carcass data collection or research studies. It is very evident that some field graders are impacted by university personnel or supervisors in the grading area even if their performance is not being evaluated. Thus, USDA field graders being unaware of data collection was the highest priority of the industry and USDA. This served as a workable approach since the fiscal ramifications of a transition based on the grading divergence between field graders and instruments could be devastating to the industry's faith in value determination based on carcass grades.

Many who have observed graders over time can attest that more divergence exists as MS increases, and several reasons can be attributed to a divergence, if observed. One obvious reason in the present study would be that some instruments only evaluated one side of the carcass, while USDA graders evaluate both sides of carcasses to determine QG, and the highest side is the carcass QG. Other more complicated explanations exist for the divergence between instrument QG and grader QG. This heteroscedasticity, or increasing variation as MS increases would seem logical and understandable as evaluation of increased distribution and amounts of marbling would be more difficult to assess, especially in the short time available to evaluate carcasses at current industry chain speeds. A scientific explanation of this phenomenon can be described as "numerosity", the number of objects in a set (Piazza and Izard, 2009). Researchers have shown that as the number of objects (in this case amount of marbling) increase it is more difficult for humans to accurately and consistently determine amount. Also, these researchers have shown that the more often a person is exposed to the number of objects or sequence, the more likely they are to accurately repeat the sequence. This phenomenon is reflected in the precision and accuracy to assess MS at lower degrees because those (Slight and Small degrees) occur more frequently and helps explain the difficulty of consistently and accurately evaluating higher MS. This also offers a reasonable explanation to plant personnel why relief graders show different grade patterns than the graders that routinely grade at the same plant.

Analysis of data by E+V and USDA confirmed the presence of a divergence between instrument QG and grader QG (Table 2). Also included with each analysis are the quality grade distributions that would result by adjusting critical marbling lines to the calculated divergence (Table 3). This analysis confirmed packers' and others' concerns that a reduction in Choice and Prime carcasses would result with the use of instrument assessed QG if applied at that time. In addition, the divergence between instrument QG and grader QG was greater at the Prime line than at the Choice or Select grade lines, as expected based on explanations provided above. To adjust MS, E+V analyzed data and developed an adjusted MS (adjusted MS = MS × Factor + Offset) using non-linear regression to minimize grade distribution differences to more closely align instrument assessed MS with USDA field grader assessed MS. In

addition, USDA adjusted MS based on their analysis of the data. Data were considered a normal distribution and a cumulative function was used incorporating non-linear regression to minimize sum of squared residuals. Both E+V and USDA suggested an adjustment to the Choice line (original approval of 395 MS) of 19 units setting the line at 376 to closely mimic USDA field graders visual assessment of QG (Table 2 and 3). This adjustment was accepted by E+V, industry, and USDA directors and administrators. The Prime line was more difficult to adjust because of increased marbling (amount, size, and distribution) and the variation in marbling assessment of experts and field graders, as well as instrumentation. The original instrument approval of 695 based on "gold standard" of USDA meat grading supervisors was adjusted to 630 and 656 by E+V and USDA, respectively. To more closely represent percentage of carcasses actually grading USDA Prime (Table 3), the E+V adjusted value of 630 was selected by industry and USDA officials, as the E+V adjustment would classify 1.6% of the 1.22 million carcasses USDA Prime based on MS; actual USDA QG assessed 1.5% of these carcasses USDA Prime. The Select line was adjusted from the original approved MS of 295 to 283 based on USDA data analysis. This adjustment was accepted by E+V, industry, and USDA directors and administrators.

Phase II

It was determined from Phase I that the source of the divergence be determined and proposed how instrument

Table 2. Critical marbling lines obtained by an analysis of the marbling score/USDA quality grade matrix (n = 1,222,722 carcasses) from E+V instrument with PRIME I approval¹, E+V suggested adjustment³, USDA suggested adjustment⁴

Grade Line ¹	Instrument ²	E+V Adj ³	USDA Adj ⁴
USDA Select	295	292	283
USDA Choice	395	376	376
USDA Prime	695	630	656

¹Instrument assessed marbling scores respective quality grade - 295 = Select⁰⁰; 395 = Choice⁰⁰; 695 = Prime⁰⁰.

Table 3. Quality grade distribution determined from E+V instrument with PRIME I approval², E+V suggested adjustment³, USDA suggested adjustment⁴ (n = 1, 222,722 carcasses) and actual USDA Quality grade⁵

Grade Line ¹	Instrument ²	E+V Adj ³	USDA Adj ⁴	QG ⁵
USDA Select, %	51.9	42.5	42.0	41.8
USDA Choice,%	47.5	55.8	57.0	56.7
USDA Prime, %	0.5	1.6	1.1	1.5

¹Instrument assessed marbling scores and respective quality grades - 295 = Select⁰⁰; 395 = Choice⁰⁰; 695 = Prime⁰⁰.

augmented QG could be transitioned transparently for official use without a major disruption in beef grading and marketing. Thus, USDA conducted a second phase of the Foundation Trial that consisted of USDA field graders, instruments and an expert panel (two USDA representatives and two academicians).

The objective of Phase II was to first validate instrument performance to ensure instruments performed as they were originally approved (PRIME I) and then to identify the source of the divergence among USDA field graders or instruments, as well as estimate national grade lines. Captured ribeye images from Phase I of the Foundation Trial were reviewed by the expert panel to assess MS and conformance of the image capture process. The same nine plants that were used in Phase I supplied raw and processed images along with official USDA grade data (both quality and yield) for all carcasses for review by the expert panel.

Images and data were collected and partitioned by E+V to provide equal observations covering both sides of each of the critical marbling lines for Select, Choice, Premium Choice and Prime grades (degrees of marbling of Traces, Slight, Small, Modest, Moderate and Slightly Abundant). Images were selected by E+V to ensure the image collection adequately represented the diversity of graders within shift, within plants, and across all dates. Images and data from

13,190 carcasses, representing three different production days, comprised the total data pool available for review.

Carcass images and data were downloaded to a remote review site, pooled, and sorted for review and classification by the expert evaluation panel. Raw and processed images were displayed through four similar monitors, each coupled to a central computer. Panel members independently evaluated raw images for MS. The panel also reviewed images to evaluate factors that influence technology performance. Official USDA marbling cards served as a reference for the expert panel. The panel reviewed raw and processed images for 5,377 carcasses over the 3-d period. The data were analyzed to determine the critical marbling lines for Select, Choice, and Prime grades. The critical marbling lines were determined for USDA applied field grades and the expert panel determined marbling degrees. These were compared to those of the instrument.

Independent assessment by an expert panel revealed that the panel was more accurately aligned with instrument QG rather than field QG (Table 4). Examination of the data on a plant-by-plant basis indicated that the panel was aligned with instrument QG in five out of the nine plants and intermediary to instrument QG and field QG in two. There was no difference among the panel, the instrument, or USDA applied field grades in two of the plants. This latter observation suggests that some inconsistencies exist in instrument use and/or in the uniformity of USDA applied field grades among the plants. Nevertheless, the source of divergence inevitably resulted from USDA field graders because the panel aligned with the instrument in seven of the nine plants.

Therefore, transitioning into instrument augmented grading, given the observed divergence, would appear to have a disruptive impact on livestock prices, as well as for retailers, restaurateurs, and consumers. The value change in grade resulting from the divergence was estimated using reported national carcass premiums and discounts for the calendar year 2006 (Table 5). A grade change resulting from USDA field grades to instrument-based grades

Table 4. Critical marbling lines obtained an analysis of the marbling score/expert panel/USDA quality grade matrix (n = 5,377 images) from E+V instrument with PRIME I approval², expert panel of USDA and academicians assessed from images via monitors in controlled setting³, and assessed USDA Field Grade line⁴

Grade Line ¹	Instrument ²	Expert ³	Field Grade ⁴
USDA Select	295	290	280
USDA Choice	395	391	374
USDA Prime	695	696	658

¹Instrument assessed marbling scores and respective quality grades - 295 = Select⁰⁰; 395 = Choice⁰⁰; 695 = Prime⁰⁰.

Table 5. Financial impact of carcass premiums and discounts that would result from the change in quality grade distribution determined from E+V instrument with PRIME I approval³, E+V suggested adjustment⁴, USDA suggested adjustment⁵ and actual USDA Quality grade⁶

Value premium/discount ¹	Instrument ³	E+V Adj ⁴	USDA Adj ⁵	QG ⁶
USDA Select, \$/cwt	-7.25	-5.93	-5.85	-5.83
USDA Choice, \$/cwt	1.51	1.77	1.81	1.80
USDA Prime, \$/cwt	0.05	0.14	0.09	0.13
Average \$/cwt	-5.69	-4.02	-3.95	-3.90
\$/cwt change from USDA field grades to instrument grades	-14.33	-0.94	-0.43	-
Total loss of carcasses graded in 2006, 26.2 million ² , \$	-375,472,066.00	-24,742,006.00	-11,296,563.00	-

¹Values were calculated using the national carcass premiums and discounts listed in 2006 Annual Meat Trade Review (Livestock and Grain Market News, USDA).

²National Summary of Meats Graded – Calendar Year 2006 (Meat Grading and Certification Branch, USDA)

would result in \$14.33 loss per carcass given the outcome of the 1.22 million head data set of Phase I of the Foundation Trial. Extrapolating this loss to the 26.2 million carcasses graded in 2006, would produce a loss of \$375 million. It would be anticipated that market dynamics would lead to adjustments through supply and demand and thereby offset the lost value of this example. However, the time-frame for adjustment would most likely be measured in multiples of years rather than in months (Considine et al., 1986). Consequently, it would seem that adjusting the instrument would be an effective solution to more closely align with current USDA field graders and make for a smoother transition to instrument-based MS assessment. Adjusting the instrument grade output using E+V's suggested adjustment would reduce the loss to \$0.94 per carcass, while using USDA's divergence assessment would reduce the loss to \$0.43.

Figure 1 illustrates the adequacy of each assessment by showing the percentage of USDA Select, Choice and Prime carcasses and their instrument MS. The intersection of these series (the point where successive grades cross) graphically represents the critical marbling lines (Slight/Small; Moderate/Slightly Abundant): the point where carcasses have a 50-50 chance of being one grade or the next. The two vertical "gold" lines, one at an instrument MS of Slight⁹⁵ and the other at Moderate⁹⁵, represent the USDA-established instrument critical marbling lines for Choice and Prime, respectively. For an ideal assessment, the Select-Choice crossover and the Choice-Prime crossover should align with the respective "gold" vertical lines. More simply explained, instrument assessment would result in similar evaluation of MS conducted by USDA field graders assessment of USDA QG, thus, minimizing changes to current percentages of USDA Select, Choice and Prime carcasses. For instruments to assess MS more similarly to field graders, E+V's and USDA's calculated divergence results of Traces⁸³, Slight⁷⁶, and Moderate³⁰ would be used to adjust variables of instruments for an Alignment Trial. Since the results between the estimates of E+V and USDA differed for the Prime line and that the value for the Select line was extrapolated, the Alignment Trial would be used to further refine the grade lines by allowing field graders to view the instrument carcass data and have the opportunity to override the proposed instrument grade.

ALIGNMENT TRIAL

The first phase of the Alignment Trial involved input from USDA graders. Graders were acclimated to the instrument displays during a one-week period followed by a three-week data collection phase. Data were collected on 422,863 carcasses from eight plants. Graders used the instrument data and input grade overrides when there was a difference between the instrument MS and their evaluation. Data included instrument MS, final QG, a blinded grader code, and grader overrides. Images were random-

ly selected within MS for a second phase and consisted of 396 images around the key marbling lines ± 40 degrees. Both, USDA-AMS LPS Program and the USDA-Agriculture Research Service (ARS), analyzed grader and instrument data independently by shift and plant.

Also, USDA conducted another image review using an expert panel consisting of two USDA representatives and two academicians. The review was used to validate instrument performance to ensure instruments performed as they were originally approved. As before, instruments were found to be operating as approved.

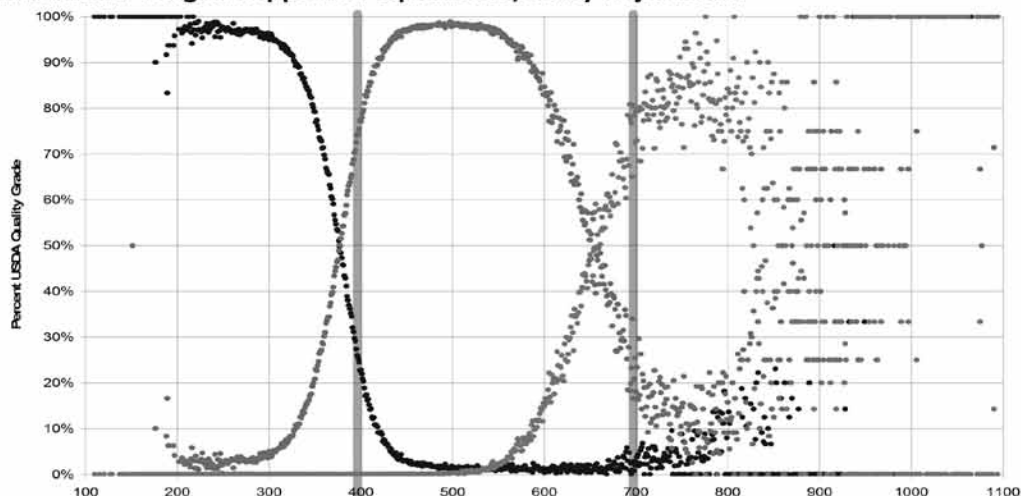
The results from analysis by USDA-AMS LPS Program and USDA-ARS differed by only two MS degrees (units) for the Select, Choice, and Prime lines. Industry and USDA agreed to further analyze the results and the resulting averages were used: Traces⁸³ for the Select line, Slight⁶¹ for the Choice line, and Moderate³⁸ for the Prime line.

In 2009, after instrument adjustment to align with USDA field graders' assessments of QG, plants gained PRIME II approval and began use of instruments for MS assessment. Thus, instrument output for MS were adjusted so that they were closely aligned to USDA field grader MS assessment and seamless transition resulted from implementation of instrument augmented QG. Instrument output (after adjustments) from this grade line summary of over 400,000 carcasses showed the Select line at 295, the Choice line at 403, and the Prime line at 702. This trial verified that instruments were calibrated and aligned correctly with USDA field graders. The instrument adjustments were not made with the intent of lowering critical grade lines or output MS; conversely, they were made to accurately reflect USDA field graders to continue beef grading as each segment of the industry is accustomed to and expects.

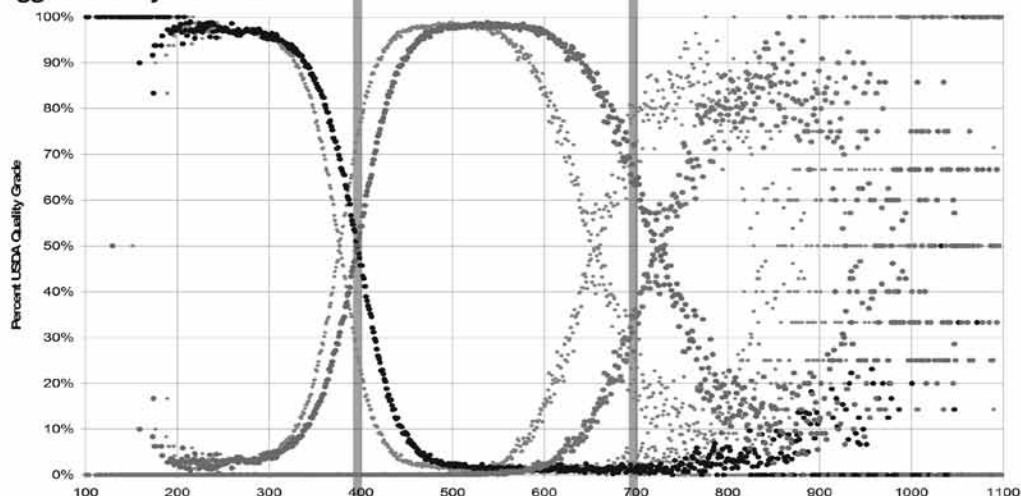
NATIONAL BEEF QUALITY AUDIT – 2011

Gray et al. (2012) and Moore et al. (2012) surveyed commercial beef processing facilities across the nation to evaluate quality and yield grade characteristics assessed by instruments and by USDA personnel, respectively, of carcasses for the 2011 National Beef Quality Audit (NBQA). This is the first NBQA where instrument grading was being utilized for assessment of MS. The instrument assessment data (Gray et al., 2012) showed similar frequencies to in-plant chilled carcass assessments (Moore et al. 2012): USDA Prime – 2.7% and 2.1%; USDA Choice – 61.5% and 58.9%; USDA Select – 31.5% and 32.6%; Other – 4.3% and 6.3%, respectively. In addition, these studies found very similar mean MS for in-plant assessments of Small⁴⁰ (Moore et al., 2012) and instrument assessments of Small⁵⁰ (Gray et al., 2012). These results are extremely positive for the credibility of instrument grading and its relationship to field grading assessments. The adjustments made to camera settings based on data from the Foundation and Alignment Trials discussed above are justifiable and warranted based on data observed in NBQA.

e+v Instrument - Original Approved Equation w/o Any Adjustment



e+v Suggested Adjustment



USDA Suggested Adjustment

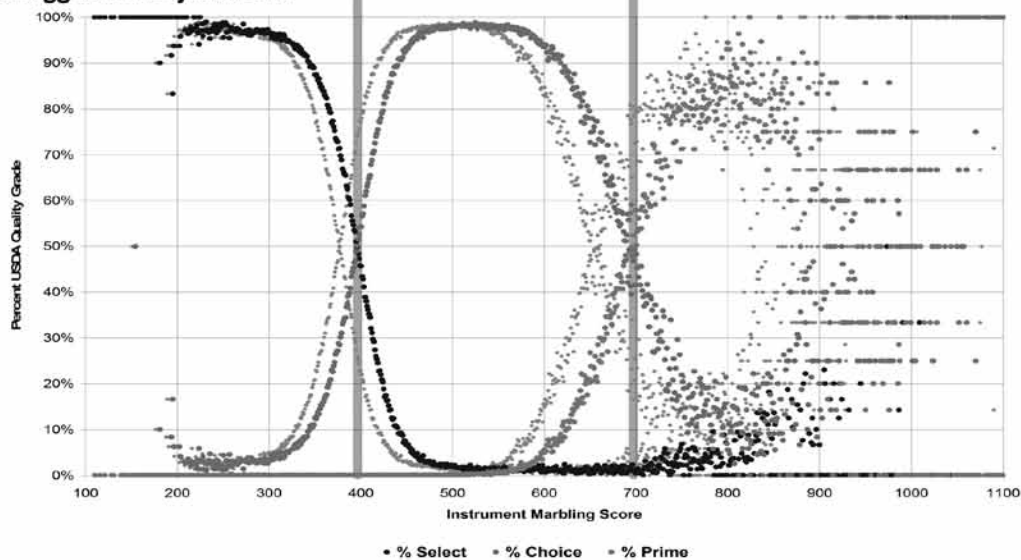


Figure1. Scatter graphs for the three scenarios of Table 3. Each chart illustrates the relationship between the instrument marbling score and the percentage of carcasses having a USDA quality grade of either Select, Choice or Prime (n = 1,222,722). Each vertical “gold” line represents an instrument critical marbling line for a change in USDA quality grade. The gold line at 395 represents the instrument’s Select to Choice grade line and the one at 695 represents the Choice to Prime grade line. Slight¹⁰⁰ degree of marbling = 300.

RELATIONSHIP OF INSTRUMENT MARBLING ASSESSMENT TO SENSORY CHARACTERISTICS

The USDA beef carcass quality grades are designed to segment carcasses of similar palatability into groups, and as such, value determination of carcasses and their cuts is primarily related to USDA QG. As beef carcass values continue to reach all time record levels in total price and price/cwt (USDA Market News, March 24, 2014), determining QG accurately, precisely, and consistently determining QG is more critical than ever. Along with price, retailers, restaurateurs, and consumers expect higher USDA QG to provide an increased overall eating experience. Emerson et al. (2012) evaluated the effectiveness of instrument MS for categorizing beef carcasses according to differences in sensory attributes. Results from their study found a strong, positive correlation ($r = 0.78$) between overall sensory experience and instrument MS. In addition, researchers showed virtually a linear increase in sensory panel juiciness and flavor (meaty/brothy and buttery/beef fat) ratings as MS increased, as well as improvements in sensory panel tenderness ratings of steaks from both steers and heifers as MS increased. Specific increases were shown in sensory panel ratings at value determining MS, including Traces/Slight, Slight/Small, Small/Modest, and Moderate/Slightly Abundant: USDA Select, Choice, Premium Choice, and Prime grade lines, respectively. Warner-Bratzler shear force values (WBS) and slice shear force (SSF) values were not as highly correlated with instrument assessed MS, $r = -0.48$ and -0.45 , respectively. However, both shear force values decreased as MS increased; WBS decreased significantly between Slight/Small MS, as well as Small/Modest MS, while SSF significantly decreased between Slight/Small MS but not between Small/Modest. Along with these positive results verifying the validity and effectiveness of instrument MS, Emerson et al. (2012) showed that probability of positive sensory eating experience increased significantly at all value determining MS (Slightly Abundant > Moderate = Modest > Small > Slight > Traces).

Smith et al. (1984) found similar results when comparing expert MS evaluation with sensory panel ratings and WBS. However, results were not as conclusive at value determining MS. They did show that, as MS increased, overall sensory ratings increased and WBS decreased. In addition, these researchers observed higher percentages of steaks with the probability of positive overall palatability as MS increased. Other researchers have also shown increased palatability ratings or decreased WBS as MS increases (McBee and Wiles, 1967; Tatum et al., 1980; Dolezal et al., 1982). In contrast, several have reported little to no association between sensory ratings and/or WBS with MS (Carpenter et al., 1972; Parrish et al.; 1973, Davis et al., 1979). Nevertheless for almost 90 y, MS and maturity classification have resulted in the most viable method to non-invasively, rapidly, and cost effectively segment carcasses into expected palatability groups

or maybe more accurately described – groups with progressively increased probability to produce an acceptable eating experience (i.e., USDA Prime less variation than USDA Choice less variation than USDA Select).

Thus all segments of the industry desire to find a more accurate means to predict palatability and assess MS; therefore, researchers, industry, and USDA moved forward in development of technology/instruments that can accommodate grading beef carcasses at similar speeds and conditions as humans. Both instruments currently approved by USDA to assess MS have proven to be effective and more consistent than USDA field graders. Therefore, beef producers, processors, restaurateurs, retailers and consumers should be confident in the ability of instruments to assess MS and augment USDA QG.

QUALITY GRADE UPSWING

According to the five National Beef Quality Audits, cooler assessments of percentage USDA Prime, Choice and Select were 2.3, 52.7 and 36.9% respectively in 1991 (Lorenzen et al., 1993); 1.6, 48.2 and 46.5% in 1995 (Boleman et al., 1998); 2.0, 49.1 and 42.3% in 2000 (McKenna et al., 2002); 2.6, 51.9 and 40.2% in 2005 (Garcia et al., 2008); and 2.1, 58.9 and 32.6% in 2011 (Moore et al., 2012). These percentages are based on evaluations by personnel of the Meat Grading and Certification Branch, AMS, USDA.

Nonetheless, some posed concern that instrument assessment of MS caused increased percentages in USDA Prime and Choice carcasses when implemented in 2009. Data presented by AMS show that the number of carcasses grading USDA Select has consistently decreased since 2006 while USDA Choice carcasses have increased, and USDA Prime percentages have slightly increased each year since 2007 (Yates, 2010). In 2001 and 2002, USDA reported the highest percentages of USDA Prime carcasses, greater than 3.5%, in the last 30 y (Yates, 2010). However, a specific concern after instrument implementation was the increase in percentage of USDA Prime carcasses in plants utilizing instrument augmented grading in Kansas and Nebraska. Additionally, percentage USDA Choice increased while percentage USDA Select carcasses decreased in facilities soon after implementation. This same pattern also was observed in Texas plants implementing instrument grading. Seasonal patterns of higher and lower quality grading carcasses have long existed in the industry, and instrument implementation in the plants of concern occurred during seasons traditionally resulting in higher quality grading carcasses (Yates, 2010).

Needless to say, many factors could have attributed to the increase with no relation to instrument assessed MS. Corah and McCully (2010) published a paper to evaluate factors that might be contributing to the increase in quality grade percentages. Authors noted several key factors including genetics, increase in black-hided cattle on feed, increase use of distiller's grains, feeding conditions, in-

crease in number of heifers on feed, and change in compositional end point. Along with these factors, increase in Choice/Select spread and premiums paid for Top Choice cattle on quality-based grids have economically impacted producers and feeders to make selection and feeding decisions to improve MS. In addition, four NBQAs conducted in 1991, 1995, 2000, and 2005 showed “too few USDA Choice Carcasses” or “inadequate marbling” as a “top ten greatest quality challenge or concern for packers” (Smith et al., 1992; Smith et al., 1995; Roeber et al., 2002; Shook et al., 2008). In the 2011 NBQA, Igo et al. (2013) reported that packers, retailers and restaurateurs ranked “eating satisfaction” as the second most important quality characteristic in their respective industries. The findings and challenges of all five NBQAs have been widely disseminated to industry organizations, producers and feeders to encourage improvement in genetics, selection, feeding and management practices. Thus, improvements in MS and QG also could be attributed to producers and feeders taking an active, aggressive approach at meeting consumer demands, as well as taking advantage of quality-based marketing grids.

CAMERA OVERRIDE, RE-GRADES, AND CERTIFICATION

Beef carcass instrument grading procedures provide guidelines to USDA field graders for override procedures of instrument assessment. Currently, graders will accept the instrument grade output for each carcass unless carcasses are not presented in accordance with official USDA Beef, Bullock and Bull Grading Methods and Procedures and in compliance with USDA Grading and Verification Division Instruction 500 (GVD 500) and 515 (GVD 515). Carcasses must be adequately chilled, properly split, and properly ribbed a minimum of 10 min prior to instrument assessment (GVD 500). Adequate chilling in accordance with GVD 500 suggests carcasses be chilled to < 40°F. Instrument grading procedures in GVD 515 and PRIME I and II also outline protocols and responsibilities of establishments and AMS for approval, calibration and verification of instruments, as well as operator and technician training.

The following describes instrument override procedures outlined in GVD 515. Improper presentation currently includes: 1) ribbed on a bias, 2) fat trim or fat pulls (if yield grading), 3) mis-splits not allowing proper evaluation of the bone surfaces, or 4) carcasses exhibiting a surface other than the 12th-13th rib cross section. Also, instrument data will not be accepted if carcasses presented have: 1) frozen ribeyes, 2) dark cutting characteristics, 3) advanced maturity for instrument assigned grade, 4) blood shot area of more than a small amount, or 5) callous areas in excess of ½ square inch. Additionally, instrument grade will not be accepted if carcass ID number does not match the monitor carcass ID number. Finally, instrument grade will not be accepted if MS is drastically different than assessed by USDA field grader (instrument MS is more than

100 degrees from USDA field grader assessed MS). Data provided to the committee by USDA-AMS on carcass presentation and image quality from November 2009 through September 2013 on 161,889 individual carcass audits from 10 processing facilities utilizing instruments describes camera and plant performance under operating conditions. Results from this audit indicate that when instrument assessed ribeye area (REA) was over-traced, 99% of REAs reviewed were within the instrument approval performance criteria of ≤ 1.5 in² (0.5 YG units). When instrument assessed REA was under-traced, 99% of REAs were ≤ 1.5 in². Additionally, 100% of carcasses had debris area on the ribeye of < 1.0 in² (99% < 0.5 in²) represented in the evaluated REA image and 97% of images evaluated were rated as “Sharp and Clear” by in-plant graders. In addition to image quality and REA measurement accuracy, graders also evaluated carcass splitting, ribbing and correct grade stamp application. Audit results suggest that improvements in carcass presentation could be made, as 19% of carcasses presented were split such that the vertebral column could not be appropriately evaluated and 17% of carcasses were mis-ribbed exposing an interface other than the 12th-13th rib cross-section of the longissimus muscle. Audit results additionally indicated that 100% of grade stamps reviewed in this sample were correctly applied. This review committee agrees with current override protocol with the addition of other gross image capture issues, which would include improper camera placement, debris on ribeye surface exceeding ½ square inch, and mis-ribbed carcasses being ineligible for either instrument or visual assessment for the purposes of official grading.

In accordance with GVD 515, carcasses are eligible for instrument or visual assessment for the purpose of re-grading as requested by the plant. If presented for visual re-grade evaluation, graders can override QG when visual assessed MS is 35 units or greater from the instrument and would result in a different QG. Carcasses presented for re-grades using instrument assessment may be re-imaged by the on-line instrument on the grading chain or by an approved portable instrument on stationary re-grade rails. Both online and portable instruments must be calibrated and validated daily. Carcasses may be re-imaged a maximum of three times for re-grade purposes. Instrument operators must wait a minimum of 5 sec before taking additional images to allow heat from the previous image capture to dissipate. Graders will use the acceptable image resulting in the highest grade. Carcass grades assessed only by USDA field graders are eligible for re-grade as many times as the plant requests and for no maximum days after initial grading. Thus, OIG questions if re-grade requests should be limited. This committee believes re-grade requests and standards should apply to both instrument assessed carcasses and visually assessed carcasses. Options for re-grades could include: 1) no re-grades, 2) limited number of re-grades (i.e. 1 static re-grade), or 3) unlimited re-grades but should be consistent and transparent for all plants or those requesting grading services.

Certification programs are vital for value-addition to all segments of the beef industry. The initial government issued program (G1), Certified Angus Beef, began in the late 1970s. With a certification program request to AMS, many programs have been developed by producers, processors, marketers or retailers to increase value and “brand” beef. The programs require certification approval and G-schedule assignment by AMS. Then, carcasses are identified in-plant with the corresponding G-schedule stamp, and the certification approval stamp is applied by USDA field graders. The OIG audit report states concerns regarding certification process by some plants that use instrument assessed MS to determine QG, but use USDA graders to assess qualification for certified programs. Another charge of this review committee is to determine if this hybrid system should be allowed or if plants using instruments to determine QG should be required to use the instrument assessed MS for certification of carcasses. Based on discussions with AMS officials and some certification program officials, in plants using the hybrid system, there appears to be a clear incentive to choose subjective grading over instrument assessment when evaluating the Modest MS for certification programs. However, an argument for the hybrid system is that similar evaluation for adjustment of the Modest MS line (the MS most often associated with certified programs) was not conducted when instrument grade assessments were adjusted with data from the Foundation Trial above. Several factors can impact how the instrument or humans interpret MS, including sections of the ribeye, distribution and size of marbling, color of lean, along with others. Moreover, as previously discussed, evaluation of humans can be influenced by such things as the Hawthorne effect and numerosity. Also, the grader in these hybrid systems does not assign a MS; he or she simply makes a determination of “qualify” or “not qualify” for the certified program assigned by the plant. Current instruments use a simple linear relationship with lines drawn at Slightly Abundant MS (USDA Prime) and Small MS (USDA Choice) to determine the Modest MS line. Today, three systems are in place for certification programs: 1) visual assessment of QG and certification qualification; 2) instrument assessment of QG and certification qualification; 3) instrument assessment of QG and visual assessment for certification qualification (hybrid system). This review committee believes, based on data presented, all three systems should perform equally, but based on the observed trends in certified programs relative to hybrid systems, the committee recommends that AMS evaluate the three approaches and considers if any adjustments are needed to the Modest MS line.

Another recommendation of OIG was for AMS to consult with third party experts to determine the feasibility and need for AMS to purchase a portable instrument grading system (camera). This AMSA review committee determined that purchasing a portable instrument would

be beneficial for the industry and for AMS to have a dedicated portable grading system for the purposes of human grader and supervisor correlations, as well as for evaluating the consistency and uniformity of grade application among plants grading carcasses with and without the assistance of an instrument.

CONCLUSION

Instrument assessed grading has been a desired technology for evaluating value determining factors used in the beef industry for over 30 y. Technology companies, industry partners, academicians, and government officials have worked closely to develop instruments that can accurately and effectively augment the application of official USDA Yield and Quality grades under commercial processing conditions. The AMSA committee, after analyzing data provided by AMS, has determined that instruments are performing well and are much more consistent than traditional visual assessment of marbling score to determine USDA Quality Grade. Instruments also reduce grader-to-grader and plant-to-plant variation. Additionally, instruments are effectively sorting carcasses into expected palatability groups, the major goal of USDA Beef Carcass Quality Grades. Responses have been developed and provided to AMS for presentation to OIG based on specific recommendations presented in their audit report. Instrument grading should increasingly be utilized by the industry and further innovations and improvements pursued, as it is well documented that it is effective for assessing marbling score and augmenting USDA Quality Grade application.

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