Meat and Muscle Biology™

Short Communication

# A Comparison of Three Camera Technology Predictions of Intramuscular Fat Percentage in F1 Wagyu

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**Abstract:** The prevalence of highly marbled cattle breeds, such as Wagyu, has increased in the US due to consumer demand for higher-quality beef. The ability to grade highly marbled carcasses accurately and consistently, particularly with quantifying intramuscular fat content for validation, remains a challenging task for the Wagyu beef industry. New camera grading technologies have been proposed by VIAS VBG 2000 (e+v Technology GmbH & Co. KG, 2021), Meat Image Japan (MIJ), and MasterBeef (MB) for Wagyu-influenced beef carcass assessment based on advanced image analysis. However, the intramuscular fat measurements of these camera technologies and the actual percent intramuscular fat (%IMF) in the *longissimus* at the 12/13th rib have yet to be investigated. Chilled carcasses ($n = 173$) from F1 Wagyu cattle were ribbed between the 12th and 13th ribs, and the left carcass sides were imaged with the E+V, MIJ, and MB cameras. Additionally, the marbling score was assigned by a team of 3 US Department of Agriculture (USDA) graders. Samples from the *longissimus thoracis* were collected, and the %IMF of the muscle was determined in triplicate. Linear regressions and descriptive statistics were done using JMP (Statistical Discovery, NC, USA) software. Camera fat-related measurements were linearly correlated, and $R^2$ was calculated. The E+V camera had the highest %IMF predictability of all cameras ($P < 0.0001$) using the marbling score ($R^2 = 0.6450$) estimate. The MIJ camera presented prediction accuracy between the other 2 technologies ($P < 0.0001$) of %IMF with identical $R^2$ for fat percent and fat score estimates ($R^2 = 0.5952$). The MB camera had the lowest predictability ($P < 0.0001$) of %IMF using the measured marbling score ($R^2 = 0.3269$), marbling area ($R^2 = 0.3333$), and marbling percent ($R^2 = 0.3269$) estimates from the instrument. As technology advances, new technologies will provide alternative means for grading Wagyu-influenced carcasses. Additionally, these findings could aid the implementation of the USDA pilot program for remote carcass grading.

**Key words:** Wagyu, camera, quality grading, intramuscular fat content
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## Introduction

In January 2024, the USDA Agricultural Marketing Service started a pilot program allowing official quality grading and certification using imaging technology for remote carcass grading (USDA, 2024). Thus, it is pivotal to understand current camera technologies and their ability to analyze meat quality attributes.

The most critical factors influencing beef consumers' eating experience are tenderness, flavor, and juiciness. Essentially, if tenderness is at an adequate level, flavor becomes the major element that determines overall liking (Miller, 2020). Moreover, research has shown that intramuscular fat content can affect palatability and flavor (Smith et al., 1987). High intramuscular fat (marbling) has been associated with a positive impact on meat flavor (O'Quinn et al., 2012; Hunt et al., 2016). The average marbling score of carcasses from fed beef cattle has increased throughout years of selection (Gonzalez and Phelps, 2018). In 2022, the quality grade distribution of fed cattle harvested in the US was 8.7% USDA Prime, 70.4% USDA Choice, 17.0% USDA Select, and 4.84% other (USDA, 2023); thus, approximately 9% of US cattle could be considered highly marbled (slightly abundant or higher marbling scores). Accurate, consistent, and objective carcass assessment systems are essential for the meat industry to capture differences in marbling that affect eating quality and economic value.

As highly marbled carcasses become readily available, it is critical for processors to take advantage of technological modernizations to categorize and merchandise beef according to its intrinsic quality characteristics. Advances in machine learning through image analysis have resulted in the development of new objective carcass evaluation tools. Many of these cameras take an image of the *longissimus thoracis* muscle after the animal has been ribbed between the 12th and 13th ribs. These cameras objectively measure and predict characteristics such as marbling, fat content, ribeye area, and color from that image. Three existing and emerging cameras evaluated in this study included the Meat Image Japan (MIJ, Japan) camera, the MasterBeef (MB) (Australia) camera, and the VIAS VBG 2000 (E+V, Germany) camera. The E+V camera was developed in conjunction with the US Meat Animal Research Center, and it is currently used in the US, Canada, Australia, Mexico, and Russia (e+v Technology GmbH & Co. KG, 2021). The MIJ camera was developed in Japan by an R&D team led by Professor Keigo Kuchida and is used for grading carcasses in both Japan and Australia (Australian Wagyu Association, 2024). The MB camera was developed in Australia by Darren Hamblin and Peter Hobbs in collaboration with iScape, and now it is being used by 40 stakeholders, including South African Wagyu breeders (Condon, 2020). The MB system is a handheld smartphone with a high-resolution camera that works through a mobile application. Al/l cameras' systems and software were developed to objectively assess beef carcass characteristics through image analysis of value-defining carcass attributes. The comparison of different camera technologies is of paramount importance due to varying levels of accuracy, camera and software adaptability, system scalability (line speed and volume), and cost. Therefore, supply chains should consider multiple elements when selecting camera technologies to objectively evaluate and grade beef carcasses.

Currently, the US beef industry relies heavily on USDA Quality Grades to predict the palatability of beef. There are no official references above Moderately Abundant marbling for highly marbled carcasses. In some cases, the intramuscular fat content of carcasses can exceed the existing marbling score scale (e.g., Extremely Abundant). Therefore, it is necessary to validate the relationship between new camera technologies and extracted percent intramuscular fat (%IMF) content in addition to USDA Marbling Scores. This study compares %IMF and marbling score predictability of the E+V, MIJ, and MB based on their unique fat measurements.

## Materials and Methods

### *Camera data collection*

A team of 3 USDA graders evaluated the left side of 176 F1 (50%) Wagyu carcasses after 24 h of postmortem chilling in a commercial beef processing facility. The same carcass sides were imaged with the E+V, MIJ, and MB cameras. Operators were trained according to manufacturer guidelines before imaging, and all measurements were taken by the same operator on the same day in a stationary rail. The attributes evaluated by each camera and an explanation of each variable are in Table 1.

### *Fat content*

Following carcass grading and evaluation, a sliced sample of the left side *longissimus thoracis* approximately 5 mm thick was taken from each carcass and transported under refrigeration to the Center for Meat Safety and Quality at Colorado State University. Subcutaneous fat was removed, and all samples were then flash-frozen with liquid nitrogen and pulverized. Fat extraction was done as described by Swing et al. (2021). Briefly, one gram of the sample was weighed and placed in a 50-mL conical-bottom tube (VWR North American Cat. No. 8939-658; PA, USA), and 20 mL of 2:1 chloroform:methanol solution were added. Using a homogenizer (Scientific Pro homogenizer model 250; CT, USA), each sample was homogenized at the sixth speed for 30 s. Samples were then agitated on an orbital shaker (Burrel Corporation model 75; PA, USA) at room temperature for 20 min at 100 rpm. Homogenate was filtered using an ashless filter paper (Whatman #42 Cat. No. 1442-150; ME, UK) into prelabeled 20-mL glass vials. Four mL of 0.9% sodium chloride (NaCl) solution was added to each tube. Samples were covered with a plastic wrap

**Table 1.** Measurements and terminologies used in MB, MIJ, and E+V cameras

| Camera | Measurements | Definition |
|---|---|---|
| **MasterBeef** | Eye Muscle Area | Full eye muscle area measurement ($cm^2$) |
| | Fat Depth | Rib fat thickness (mm) |
| | Marble | Marbling score based on Beef Marbling Scoring |
| | Marbling Area | Area of fat taken from eye muscle area ($cm^2$) |
| | Marbling Percent | Percent marbling area |
| | Marbling Total Perimeter | Total perimeter around meat sample (cm) |
| | Meat Area | Area of meat from eye muscle area ($cm^2$) |
| **MIJ** | Dma | Rib eye area ($in^2$) |
| | DMf | Fineness index |
| | DMp (%) | Marbling percent |
| | DMs | Marbling score based on Beef Marbling Scoring |
| | Taken at | Date and time |
| **E+V** | Cam Marb Code | USDA marbling grade |
| | Cam Marb Score | USDA numeric marbling score |
| | Cam Q Grade | USDA quality grade (Prime, Choice, Select) |
| | Cam REA | Ribeye area ($in^2$) |
| | Cam Y Grade | Vision yield grade |
| | Grade Date | Date graded |
| | Grade Shrink | Difference between hot weight and grade weight (kg) |
| | Grade Weight | Weight when graded (kg) |
| | Hot Date | Date slaughtered |
| | Hot Weight | Weight when slaughtered (kg) |
| | Side ID | Carcass side |

(Parafilm M #HS234526C; WI, USA) and placed in a refrigerator at 4°C for approximately 16 h. The next day, the lower phase (with the lipid extract) was extracted using a glass pipette (Fisherbrand Cat. No. 13-678-20C; MA, USA) and placed in a preweighed labeled 16 × 50-mm scintillation vile (Fisherbrand 03-338B; MA, USA) that was placed into a 5.8-L glass desiccator (Pyrex model 3121-200; IL, USA) to dry for 2 h to evaporate residual chloroform and dried in a dry matter oven (GCA Precision model 26; IL, USA) at 100°C for approximately 16 h. Vials were allowed to cool at room temperature and weighed to calculate the %IMF of all carcass samples in triplicate.

### *Statistical analysis*

Data were exported from all 3 camera systems into Microsoft Excel (Microsoft, Redmond, WA) and checked for missing values. Three data points (carcasses) were deleted because they did not have all 3 camera outputs, leading to a total number of 173 carcasses used for this experiment. Linear regression and descriptive statistics were performed using JMP (Statistical Discovery, NC, USA), analyzing the relationship between 2 variables using the fit Y by X function.

## Results

This study aimed to describe the predictive potential of the E+V, MIJ, and MB beef grading cameras in estimating the %IMF in the *longissimus thoracis* muscle of F1 Wagyu cattle. Descriptive statistics are presented in Table 2. In this study, the E+V camera's prediction of intramuscular fat is based on USDA Marbling Scores. The $R^2$ for predictability of %IMF by the E+V camera was 0.6450, which was numerically higher than that of all other cameras' and the USDA graders' assessments. The MIJ camera assessed intramuscular fat based on marbling percent and marbling score. The estimates pertained to different intramuscular fat characteristics. Nevertheless, their predictability ($R^2$) of %IMF did not differ ($R^2 = 0.5952$). The MB estimated marbling (score), marbling area, and marbling percent. Although the measurements under consideration from the MB camera represented different aspects of intramuscular fat content within the *longissimus* muscle, the predictive capacity for %IMF of these measurements was numerically similar (Table 3) and lower than with the E+V system. Lastly, the USDA grader-assessed marbling scores resulted in an $R^2 = 0.6161$ with extracted %IMF.

**Table 2.** Descriptive statistics of percent intramuscular fat, E + V, MB, MIJ, and USDA grades.

| Statistic | %IMF* | E+V Score | MB Area ($cm^2$) | MB Marble | MB Percent | MIJ Percent | MIJ Score | USDA Grade |
|---|---|---|---|---|---|---|---|---|
| **Mean** | 14.37% | 828.78 | 57.31 | 7.73 | 22.79% | 13.48% | 3.97 | 795.08 |
| **Standard Deviation** | 4.40% | 139.05 | 16.69 | 2.06 | 6.65% | 6.61% | 1.94 | 160.60 |
| **Min** | 6.56% | 418.00 | 23.31 | 12.9 | 10.90% | 2.01% | 0.59 | 430.00 |
| **Max** | 30.64% | 1199.00 | 104.38 | 3.9 | 40.12% | 31.76% | 9.37 | 1099.00 |

*%IMF - Percent intramuscular fat content.

**Table 3.** Linear regression equations of the E+V, MB, MIJ, and USDA grader based on specific predictors

| Camera | Predictor | $P$ Value | Root Mean Square Error | $R^2$ | Equation |
|---|---|---|---|---|---|
| E+V | Marbling Score | <0.0001 | 0.0262 | 0.6450 | %IMF = −0.066833 + 0.0002541*Marbling Score |
| MasterBeef | Marble | <0.0001 | 0.0361 | 0.3269 | %IMF = 0.0494687 + 0.0121858*Marble |
| MasterBeef | Marbling Area | <0.0001 | 0.0360 | 0.3333 | %IMF = 0.0565526 + 0.0015214*Marbling Area |
| MasterBeef | Marbling Percent | <0.0001 | 0.0362 | 0.3249 | %IMF = 0.0578607 + 0.0037679*Marbling Percent |
| Meat Image Japan | Marbling Percent | <0.0001 | 0.0280 | 0.5952 | %IMF = 0.0744359 + 0.0051412*Marbling Percent |
| Meat Image Japan | Marbling Score | <0.0001 | 0.0280 | 0.5952 | %IMF = 0.0744359 + 0.017422*Marbling Score |
| USDA | Grade | <0.0001 | 0.0273 | 0.6161 | %IMF = −0.027206 + 0.000215*USDA Grade |

# Discussion

Historically, the US has relied on highly skilled USDA graders to evaluate beef carcasses based on subjective assessment of carcass characteristics. New technologies involving electronic instruments, such as high-definition cameras and advanced image learning, can promote modern alternatives to beef carcass grading. These instruments have improved beef grading accuracy by minimizing subjectivity and reducing variability across USDA graders (Jang et al., 2017). The use of high-resolution cameras can facilitate the implementation of the USDA pilot for remote beef grading.

This study aimed to determine the accuracy of the E+V, MB, and MIJ cameras in predicting %IMF in the *longissimus* muscle of F1 Wagyu beef carcasses. The E+V camera demonstrated superior performance, yielding the highest $R^2$ compared to the other 2 camera systems and the marbling scores assigned by USDA graders. Previous studies have confirmed the accuracy and precision of the E+V camera as a carcass grading tool (Allen, 2005; Dow et al., 2011). Schulz and Sundrum (2019) compared E+V measurements of % IMF at the 10th/11th rib with those obtained at the 12th/13th rib of the same carcass. Their findings were similar ($R^2 = 0.68$) to the results found in this study ($R^2 = 0.6450$) when predicting extractable %IMF using camera estimates of the marbling score (Schulz and Sundrum, 2019). The MIJ camera has previously been reported to accurately predict the quality of beef carcasses (Kuchida et al., 2000). However, recent studies suggest that the MIJ measurements can have variable precision when predicting %IMF (Stewart et al., 2021). Stewart et al. (2021) presented that the MIJ camera had an $R^2 = 0.5$ to predict %IMF. In the current study, the MIJ had a higher coefficient of determination of $R^2 = 0.5952$. Also in this study, the MB camera had the lowest $R^2$ of all 3 cameras (Marbling area; $R^2 = 0.3333$); therefore, further development and research are needed to improve the accuracy of the MB camera to establish the technology as a reliable grading tool for predicting %IMF. Additionally, with more data, researchers could better understand how the MB camera performs in different scenarios and under varying conditions.

The utilization of objective camera technologies provides an alternative for beef producers to assess carcass quality without human subjectivity. Additionally, camera technologies offer flexibility and efficiency because an individual who is not a USDA agent could be able to grade beef quality if trained properly. However, it is essential to consider that the USDA Quality Grades still hold significant value for the meat industry. In this study, subjective USDA grader assessments of marbling had the second highest $R^2$ for %IMF compared to all the camera measurements ($R^2 = 0.6161$). Undoubtedly, technology will continue to influence beef grading in the future. As technology continues to improve, its influence on beef quality grading will allow for revolutionizing improvements in efficiency and consistency.

# Conclusion

This study compared the capability of E+V, MIJ, and MB to predict intramuscular fat in the *longissimus thoracis*. The E+V camera had the highest $R^2$, followed by USDA graders, MIJ, and MB, respectively. New camera systems could serve as a tool for small and medium-sized meat processors for grading Wagyu-influenced beef carcasses. More profound knowledge of the ability of cameras to predict %IMF is needed to determine their accuracy. Additionally, the relationship between camera measurements and consumer acceptance should be further investigated.

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