THESIS

PREDICTION OF PRIMAL AND SUBPRIMAL BEEF YIELDS WITH VIDEO IMAGE ANALYSIS

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ABSTRACT

PREDICTION OF PRIMAL AND SUBPRIMAL BEEF YIELDS WITH VIDEO IMAGE ANALYSIS

An ability to segregate carcasses based on both primal and subprimal yields would further facilitate value-based marketing in the beef industry. This study was conducted to evaluate Video Image Analysis (VIA) output to predict fabricated primal and subprimal yields. Carcasses were selected based on yield grade (YG 1, YG 2, YG 3, YG 4, and YG 5) as well as hot carcass weight (< 341 kg and ≥ 341 kg). A yield dissection was performed and at each step in fabrication, recovered product weights for each carcass to remain in the study summed to ≥ 99 % of the starting chilled weight of each primal and subprimal. For yield predictions, VIA output from $12^{th}/13^{th}$ rib interface images from the VBG 2000 (single-component; n = 142, development; n = 58, validation), or from VBG 2000 output in combination with output from loin/round primal interface images from the VPS 2000 (dual-component; n = 129, development; n = 56, validation) were regressed on yields of fabricated primals and subprimals. Yield variables were predicted as a percent of the aggregate chilled carcass side weight. Results from prediction equations for primals or the largest subprimal representing a primal in the study, indicated moderate and low predictive capability for development and validation datasets, respectively. For the square cut chuck (IMPS 113), commodity trimmed brisket (IMPS120, PS0 1), ribeye (IMPS 112A, PSO 3, 5.1 cm x 5.1 cm lip-on), short plate (IMPS 121), loin primal (IMPS 172), flank primal, and round primal (IMPS 158) R^2 / adjusted R^2 values (development / validation) of 0.39 / 0.11, 0.16 / 0.05, 0.31 / 0.12, 0.40 / 0.03, 0.56 / 0.12, 0.35 / -.005, and 0.64 / -0.05, respectively, for single-component predictions and 0.60 / -0.13, 0.57 / -0.03, 0.40 / 0.08, 0.52 / -0.15, 0.66 / -3.42, 0.66 / -3.42, 0.47 / -0.004, and 0.73 / -0.10, respectively, for dual-component predictions was observed. The best performing single-component model was for the tenderloin (IMPS 189A) with R^2 / adjusted R^2 values (development / validation) of 0.42 / 0.50. The best performing dual component model was for the cap off inside round (IMPS 169A) with R^2 values (development / validation) of 0.58 / 0.30. The ability of single-component and dual-component equations to predict yields of several primal and subprimal cuts, with reasonable accuracy and precision in the development dataset, yet low accuracy and precision in the validation dataset, suggests that the VIA systems tested in this study do not have the potential as tool for more sensitive carcass segregation at this time. Further investigation to reveal the full potential of dual-component primal and subprimal cut yield prediction, perhaps looking at a sample population with greater variance (i.e., equal number of yield grades for equation development) and having VPS 2000 images available from each primal surface to provide independent variables representative of the entire carcass, is justifiable.

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CHAPTER I

OBJECTIVE OF THESIS

Objective: to develop and validate prediction equations for primal and subprimal beef yields with the e+v VBG 2000 or VBG 2000 and VPS 2000 video image analysis systems.

CHAPTER II

REVIEW OF LITERATURE

The U.S. beef industry routinely assesses cutability in order to categorize carcasses by their anticipated yield of boneless, closely trimmed retail products. Research on objective instruments to determine carcass cutability and reduce errors by USDA human graders commenced in 1978 through a cooperative effort between USDA and the National Aeronautics and space Administration Jet Propulsion Laboratory, resulting in Video Image Analysis (VIA) being identified as having the greatest potential for this purpose (Cross et al., 1983). Multiple studies, in different countries, have tested the ability of VIA instrumentation to objectively predict, or augment yield grade (YG) prediction of, beef cutout yields utilizing data produced from digital images of 1) an entire side of a hot carcass, 2) the 12th/13th rib (*longissimus* muscle) interface of a chilled carcass, or 3) a combination of output from both instruments (Borggaard et al., 1996; Cannell et al, 1999 and 2002; George et al., 1996; Jones et al., 1995; Shackleford et al., 2003; Steiner et al., 2003a and 2003b; Vote , 2003).

Cross et al. (1983) and Wassenberg et al. (1986) conducted research on first generation VIA instruments, assessing rib interfaces to predict cutability. While Cross et al. (1983) predicted 9th-10th-11th rib lean yield and Wassenberg et al. (1986) predicted percent total primal lean yield, both found that equations developed from VIA assessment had an equivalent or better ability (with the exception of one equation developed by Cross et al., 1983) to predict actual dissected yields than did equations developed from

USDA YG equation measured factors. For weight VIA predictions in comparison with USDA YG predictions, Cross et al. (1983) reported R^2 values of 0.96 and 0.94, respectively, while Wassenberg et al. (1986) reported 0.94 and 0.84, respectively. However, both Cross et al. (1983) and Wassenberg et al. (1986) underscored an inability of VIA to account for adjusted fat thickness, which is subjectively determined by graders using the established YG equation.

George et al. (1996) reported that VIA assessment of the chilled 12th/13th rib interface more accurately predicted actual boxed beef yields when equations were augmented with expert YG factors, as opposed to using VIA output-only equations (R^2 = 0.75 and 0.55, respectively). Expressed industry and USDA interest in the prospect of objective replacement of USDA graders by instrumentation led Belk et al. (1996) to conclude that, because no instrument at that time had demonstrated an ability to replace USDA graders, and until there is consensus on an instrument capable of doing so, instrumentation may be able to augment grading by providing information that cannot be provided accurately by graders.

Belk et al. (1998) conducted a study simulating instrument augmentation USDA YG application, finding that an expert panel of graders, without time restrictions to consider slaughter defects and carcass irregularities, was more accurate than VIA at assigning YG due to their ability to more accurately determine overall carcass fatness (i.e., adjusted fat thickness). In that study, 94.4 % of the sample population required some adjustment to measured preliminary yield grade (PYG) (Belk et al., 1998). In fact, several studies suggested that USDA graders are better able than instruments to establish overall carcass fatness, which is subjectively assessed (Belk et al., 1996; Cross et al., 1983; Wassenberg et al., 1986). Belk et al. (1998) rationalized that because perfectly assigned USDA YGs are accurate and reliable, errors arise in YG application largely due to the speeds at which carcasses are presented to on-line graders, which was in concurrence with a previous study by Cross et al. (1983), wherein an error rate of 11.6% in YG application occurred. Belk et al. (1998) concluded that augmenting the yield grade system with an instrument would be most beneficial if all measured YG factors could be provided to the on-line USDA grader, except for grader-determined adjusted fat thickness, and the system could couple objective and subjective measurements to calculate a final yield grade to the nearest tenth, providing greater predictive sensitivity.

VIA has shown an ability to predict yield grade factors accurately. Cannell et al. (1999, 2002), Cross et al. (1983), George et al. (1996), Shackelford et al. (1998, 2003), Steiner et al. (2003a), Vote (2003), and Wassenberg et al. (1986) all reported VIA assessment of REA was superior to subjective assessment. Despite Cannell et al. (2002) and Shackelford et al. (1998) reporting that VIA can accurately predict overall fatness to determine final YG (APYG), more research has demonstrated an inability to predict APYG more accurately than human subjective measures (Cannell et al., 1999 and 2002; Cross et al., 1983; Shackelford et al., 1998; Vote, 2003; and Wassenberg et al., 1986). Because REA and APYG are the most important YG factors, augmenting the current system of YG assignment with instrumentation to improve cutability prediction by calculating final yield grade to the nearest tenth has been the recommendation of researchers (Cannell et al., 1999 and 2002; Cross et al., 1983; Shackelford et al., 1998; Steiner et al., 2003b; Vote, 2003; and Wassenberg et al., 1986)). When final yield grade is calculated to the nearest tenth, individual subprimal yield prediction has been improved among the studies that have investigated this (Cannell et al., 1999, 2002; Steiner et al., 2003b).

Cannell et al. (1999) tested the ability of VIA to predict actual wholesale subprimal yields to three different trimmed end-points (commodity trimmed, closely trimmed or very closely trimmed; 2.54 cm maximum fat depth, 0.64 cm maximum fat depth, or ranging from 0.64 cm maximum fat depth to denuded, respectively), evaluating the best predictive capability from combinations of (1) a VIA system that evaluated whole hot carcass side images (HCVIA), (2) a VIA system that evaluated the 12th/13th rib interface images of chilled carcasses (CCVIA), (3) expert off-line USDA grader YG factors, and (4) on-line USDA grader YG factors (predicting actual wholesale fabrication yields as a percentage of carcass side weights from whole carcass sides or carcass sides with kidney, pelvic, and heart fat [KPH] removed). Cannell et al. (1999) suggested that VIA may be used to augment on-line grading for more accurate YG assignment, reporting prediction models with only VIA variables, or prediction models with a combination of VIA and human grader variables, more accurately predicted actual carcass cutout yields than YG assigned by on-line graders. In their study, R^2 values produced by prediction models with only VIA variables exceeded those produced by on-line graders and approached those produced by expert graders. For prediction of very closely trimmed wholesale yield, Cannell et al. (1999) reported R^2 values for CCVIA, CCVIA combined with HCVIA, and on-line grader of 0.68, 0.71, and 0.54, respectively.

In a similar study, testing two VIA systems from a different manufacturer that evaluated whole hot carcass side images or 12th/13th rib interface images of chilled carcasses, Cannell et al. (2002) examined the accuracy of predicting actual wholesale subprimal cuts trimmed to a 0.64 cm maximum fat depth among on-line YG (whole number), expert YG (nearest tenth), VIA instruments independently or in combination, and VIA-augmented expert yield grades. Cannell et al. (2002) reported that the difference in predictive accuracy of VIA-augmented YG was 2% less than expert yield grade (R^2 = 0.65 and 0.67, respectively) and 26% greater than online YG (R^2 = 0.39). Cannell et al. (2002) suggested VIA could be employed to augment on-line YG assignment for improved actual predicted subprimal yield accuracy.

Steiner et al. (2003b) completed a study of real-time augmented USDA beef YG application, with VIA systems from two different manufacturers, which evaluated whole hot carcass side images or 12th/13th rib interface images of chilled carcasses. Predicting actual overall subprimal cut yields from the round, loin, rib, and chuck, as a percentage of the chilled carcass side weight, it was determined that yield grade placement could be improved through an augmented system (Steiner et al., 2003b). In an augmented prediction of YG (nearest tenth), both VIA systems were more accurate than on-line grader YG (whole number) assignment; R^2 values of 0.63 and 0.60 for the VIA systems compared to 0.55 for on-line grader (Steiner et al., 2003b). For this study, instrument determined YG was calculated using HCW, actual KPH (percentage of chilled carcass side weight), VIA measured ribeye, and VIA measured fat thickness.

Shackleford et al. (1998) predicted actual yields for 14 subprimal cuts and lean trimmings for an entire carcass side. This study reported that between 46 and 82 % of the variation in weight of subprimals tested was explained by their developed prediction equations and suggested that VIA could be used to facilitate a value-based marketing system. Noteworthy in the Shackleford et al. (1998) study, was the fact that 2.54 cm steaks were collected from the 12th rib section (n = 66), from steer and heifer carcasses with 25%, 50%, or 75% Piedmontese inheritance, and analyzed by an off-line VIA system. Also, an equation for retail product yield from the study that had been developed and validated (R^2 = 0.88 and 0.91, respectively) from VIA output was augmented with hot carcass weight and used to predict individual subprimal yields on a weight basis.

VIA also has been used to predict cutability in other species. In a pork study, McClure et al. (2003) reported that weights of saleable product, fat-corrected lean, bone-in ham, bone-in loin, loin lean, and belly could be predicted with high levels of accuracy when hot carcass weight augmented VIA in prediction models; however, these equations were not validated and the researchers stated that the VIA system tested was insufficiently repeatable to be used as a value-determining tool. Another pork VIA system tested is housed in a cabinet on the conveyor of a fabrication line, collecting images of interior carcass sides or primal interfaces; the system demonstrated reasonable accuracy in total carcass cutability prediction (Engel et al., 2006; Font i Furnols and Gispert, 2009). In the lamb industry, Cunha et al. (2004) validated and improved the predictive accuracy of equations developed by Brady et al. (2003), reporting that dual-component (hot carcass and chilled carcass VIA systems) equations can explain a greater proportion of observed variation in yields of bone-in cuts of lamb compared with expert, or on-line, USDA YG. Cunha et al. (2004) also found that the chilled carcass system was accurate and repeatable, and could be used to facilitate value-based pricing.

CHAPTER III

INTRODUCTION

As the U.S. beef industry strives to incorporate a value-based marketing system, increasing carcass segregation based on expected cutability is advantageous. Yield grades (YG) are routinely assigned by USDA to reflect anticipated carcass cutability of boneless, closely trimmed retail products; however, this prediction reflects overall (total carcass) cutability. Belk et al. (1998) performed a study simulating the ability of instrumentation, specifically Video Image Analysis (VIA), to augment the current USDA yield grading system and found that YG (in whole numbers, actually stamped on carcasses) was more closely associated with Gold Standard (average of expert panel without time constraints) whole number YG than was final YG calculated to the nearest tenth. Belk et al. (1998) noted that the advantage of an augmented yield grading system is that YG could be calculated to the nearest tenth, offering greater predictive sensitivity. With use of VIA systems that assess the 12th/13th rib interface, subsequent research has evaluated and demonstrated the ability of VIA to accurately predict actual comprehensive wholesale subprimal yields in addition to overall cutability in a YG context (Cannell et al., 1999, 2002; Shackelford et al., 1998; Steiner et al., 2003). Another VIA system is available, but not yet tested in the beef industry, which is housed on a fabrication conveyer. The system has demonstrated reasonable accuracy in prediction of pork yields (Engel et al., 2006; Font i Furnols and Gispert, 2009). Shackleford et al. (1998) stated that, because most beef carcasses are merchandised as boxed-beef subprimals and the subprimal yield of individual carcasses is usually not determined, the true value of most beef carcasses is never known.

Muscle profiling research (NCBA, 2000) has generated interest in single muscle cuts. Von Serggen et al. (2005) acknowledged that interest in underutilized cuts of beef has risen significantly and consumer demand has increased the wholesale value of the chuck. Conservatively, assigning half of a five-year increase in carcass value to the chuck suggests muscle profiling research has contributed, in part, to the added $50 to $70 per head increase of market steers and heifers in the U.S. (Von Serggen et al., 2005). Beyond making decisions concerning selection of specific fabrication style based on overall carcass cutability (YG), the ability to segregate carcasses prior to fabrication, based on an expected yield of individual subprimal cuts, would be potentially valuable. The objectives of this study were to test the ability of an on-line VIA system that evaluated the $12^{th}/13^{th}$ rib interface of chilled carcasses (single component), or the ability of this system in combination (dual component) with an on-line capable VIA system that evaluated chilled-carcass primal interfaces of the loin and round to predict beef primal and subprimal yields.

MATERIALS AND METHODS

Carcass selection and evaluation by the VBG 2000

The left-side of conventionally harvested beef carcasses (n = 200, single-component; n = 185, dual-component [Table 1]) were selected and fabricated by Colorado State University (CSU) Personnel over a 7 month period at a commercial packing plant (Greeley, Colorado) to fill a 2 x 5 design matrix reflecting HCW (< 341 kg and ≥ 341 kg) and USDA YG (1, 2, 3, 4, or 5). Hot carcass sides were identified by weight for conditional inclusion in the study, pending final expert YG assignment. Heifer, steer and Holstein carcasses were also identified and included to ensure variation in the sample population. Following a 26 to 36 h postmortem chilling period, prospective carcass sides were circulated onto a grading chain, where—immediately prior to on-line grading—plant personnel using a real-time VIA system, VBG 2000 (e + v Technology GmbH, Oranienburg, Germany), captured 12th rib (*Longissimus* muscle) surface digital images from the 12th/13th rib interface. Any carcass exhibiting irregularities from the slaughter process was disqualified from inclusion in the study. After on-line grading, final YG (nearest tenth) was calculated combining VIA measured REA and APYG and KPH determined by an off-line USDA grader (unlimited in time constraints). Carcasses selected for the experiment were stored on a static rail until fabrication ensued.

VBG 2000 Image

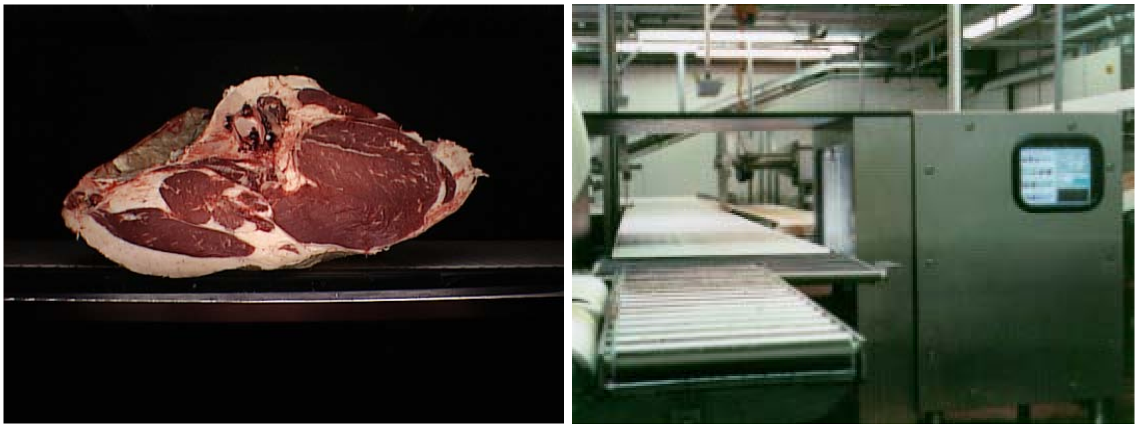
Carcass fabrication and evaluation by the VPS 2000

For dissection, only left carcass sides were used. Carcass sides were moved to static cutting tables for off-line sequential fabrication and weighing, of manufactured primal and subprimal cuts by CSU personnel to produce actual primal and subprimal yields for equation development and validation. For a carcass to remain in the study, at each step in fabrication, recovered product weights were required to sum to 99 % of the starting weight of each primal and subprimal. Primal and subprimal weights were used to derive an aggregate chilled carcass side weight.

Prediction equations were created, with responses measured as a percent (whole-number scale) of the aggregate chilled carcass-side weight, for primal or subprimal cuts manufactured according to Institutional Meat Purchasing Specifications (IMPS) descriptions (USDA, 1996), as well as for lean trimmings, fat trimmings, and bone yields from the cuts produced. Purchaser specified options (PSO) for the cuts used in this study were as follows: commodity trim, maximum 2.54 cm fat thickness at any point (PSO 1); maximum 6 mm fat thickness at any point (PSO 3); and peeled/denuded, surface membrane removed, 90 % lean exposed, and 3 mm maximum fat thickness at any point (PSO 6). The manufactured cuts included: square cut chuck (IMPS, 113); brisket (IMPS 120, PSO 1); brisket (IMPS 120, PSO 3); brisket flat (IMPS 120A); brisket point (IMPS 120B); chuck roll (IMPS 116A); mock tender (IMPS 116B); clod (IMPS 114C, PSO 3); chuck eye roll (IMPS 116D, PSO 6); underblade (IMPS 116E); boneless short ribs (IMPS 130); short plate (IMPS 121, boneless short ribs (IMPS 123D); ribeye (IMPS 112A, PSO 3, 5.1 cm x 5.1 cm lip-on); outside skirt (IMPS 121C); inside skirt (IMPS 212D); rib cap (IMPS 112D); loin (IMPS 172); striploin, 2.54 cm x 2.54 cm lip-on (IMPS 180, PSO 3);

top sirloin butt (IMPS 184); bottom sirloin butt (IMPS 185); bottom sirloin butt, flap (IMPS 185A); ball tip (IMPS 185B); tri tip (IMPS 185D); tenderloin (IMPS 189A); flank primal, untrimmed; round, primal (IMPS 158); knuckle (IMPS 167); round, inside, cap off (IMPS 169A); gooseneck, heel out (IMPS 170A); knuckle, peeled (IMPS 167A); outside flat (IMPS 171B, PSO 3); eye of round (IMPS 171C, PSO 6); heel (IMPS 171F); lean trimmings; fat trimmings; and bone.

During fabrication, a second VIA system, VPS 2000 (e + v Technology GmbH, Oranienburg, Germany), was used to capture unique primal interface digital images of the sirloin surface of the loin/round interface from each carcass side. The VPS 2000 is a stationary instrument with a cabinet surrounding a conveyer belt and capable of real-time application. However, this was the first time this system had been tested for beef yield prediction and consequently, it was temporarily installed in proximity to the static fabrication tables for off-line image acquisition.



VPS 2000 Image and System

The yield dataset was split into prediction equation development and validation datasets. Equations were created in a single-component (VBG 2000 only; n = 142, development; n = 58, validation) or dual-component (VBG 2000 + VPS 2000; n = 129, development; n = 56, validation) approach, using actual yields to derive predicted yields. There were five substitutions of right-side images from the VBG 2000 output because left-side images were not captured. The same carcasses evaluated by the VPS 2000 were also evaluated by the VBG 2000.

Statistical Analysis

Descriptive statistics, correlations between variables, and regression analyses were performed with SAS (SAS Inst. Inc., Cary, NC) using Proc Means, Proc Corr, and Proc Reg, respectively. Due to availability of a high number of output independent variables, the number of potential independent variables considered for best fit equations was reduced using multiple linear regression with forward and backward selection. For the VBG 2000 (87 variables) output data, backward selection ($\alpha = 0.001$) was used. For the VPS 2000 (631 variables) output, forward selection ($\alpha = 0.5$), followed by backward selection ($\alpha = 0.001$) was used. After the number of potential independent variables was reduced, best-fit models were established using multiple linear regression based on a lowest C_p value selection criterion. The only non-VIA variable permitted was HCW which was automatically supplied in the VBG 2000 output. For equation validation, Adjusted R^2 was estimated by hand calculation. Predicted values for validation dependent variables were generated by SAS and used to obtain sums of squares error (SSE) for predictions (i.e., error not explained by the model). Actual values for validation dependent variables were used to obtain SSE for the mean (i.e., error not explained by development data model). The actual equation used to estimate Adjusted R^2 was:

$$1-\left(\frac{\sum(y_i-\hat{y}_i)^2}{\sum(y_i-\bar{y})^2}\right)$$

RESULTS AND DISCUSSION

Descriptive statistics for the carcasses in the sample population are presented in Table 2. The original factorial design called for seven sides within each of the multiple factor levels for the development population and for the validation population; carcasses were to represent the national distribution of fed-cattle yield grades (9.3% YG 1s; 38.2% YG 2s; 41.5% YG 3s; 9.6% YG 4s; 1.4% YG 5s) as reported by USDA (2006). Substitutions not conforming to the originally designed sample population were made using the researchers best judgment (Table 1). To the extent possible, the sample population was selected to represent a considerable range of variability in carcass traits present in a commercial beef harvest facility and the large standard deviations for HCW, fat thickness, and USDA yield grade were due to intentional selection for carcass variation.

Results for equations for primals or the largest subprimal representing a primal in the study indicated moderate and low predictive capability for development and validation datasets, respectively (Table 3). Accuracy and precision, in terms of R^2 / adjusted R^2 (development / validation), for the square cut chuck (IMPS 113), commodity trimmed brisket(IMPS 120, PS0 1), ribeye (IMPS 112A, PSO 3, 5.1 cm x 5.1 cm lip-on), short plate (IMPS 121), loin primal (IMPS 172), flank primal, and round primal (IMPS

158) was: 0.39 / 0.11, 0.16 / 0.05, 0.31 / 0.12, 0.40 / 0.03, 0.56 / 0.12, 0.35 / -0.005, and 0.64 / -0.05, respectively, for single-component predictions and 0.60 / -0.13, 0.57 / -0.03, 0.40 / 0.08, 0.52 / -0.15, 0.66 / -3.42, 0.66 / -3.42, 0.47 / -0.004, and 0.73 / -0.10, respectively, for dual-component predictions. When predictions for the validation dataset were lower than the mean of actual values, it was possible to produce estimated adjusted R^2 values less than zero.

The five best performing single component models were for boneless short ribs (IMPS 123D), rib cap (IMPS 112D), tenderloin (IMPS 189A), inside cap-off (IMPS 169A), and outside flat (IMPS 171B, PSO 3) with R^2 / adjusted R^2 values (development / validation) of 0.46 / 0.27, 0.70 / 0.46, 0.42 / 0.50, 0.56 / 0.40, and 0.42 / 0.22, respectively. The five best performing dual component models were for mock tender (IMPS 116B), rib cap (IMPS 112D), bottom sirloin butt (IMPS 185), bottom sirloin flap (IMPS 185A), and cap off inside round (IMPS 169A) with R^2 values (development / validation) of 0.58 / 0.25, 0.78 / 0.26, 0.63 / 0.19, 0.49 / 0.24, and 0.58 / 0.30, respectively.

Steiner et al. (2003b) evaluated two different VIA systems that imaged the 12th/13th rib interface of carcasses. Output from VIA was then augmented with USDA expert YG factors to predict actual total subprimal, fat, and bone yields. Steiner et al. (2003b) reported R^2 values of .51 and .46 for fat, and .06 and .04 for bone from the two systems. In the present study, where HCW was the only non-VIA variable available to possibly enter into models, R^2 / adjusted R^2 values (development / validation) of 0.77 / -0.38 for fat and .73 / -.43 for bone were observed in single-component models, and 0.81 / -.46 for fat trimmings and 0.77 / -0.41 for bone in dual-component models; HCW did not a enter into any of these best-fit models. Although R^2 values were higher for predicted fat and bone in the development dataset of the present study compared to Steiner et al. (2003b), equations were not accurate and precise when tested with the validation dataset.

In this study, accuracy was far less in single component equations for brisket (IMPS 120, PSO 1), chuck roll (IMPS 116A), top sirloin butt (IMPS 184), and peeled knuckle (IMPS167A), than was reported for closely approximated cuts with single component prediction by Shackelford et al. (1998); R^2 / adjusted R^2 values (development / validation) of 0.17 / 0.04, 0.27 / -0.09, 0.33 / -0.15, and 0.42 / -0.30, respectively versus 0.59, 0.76, 0.80, and 0.78, respectively. In the Shackelford et al. (1998) study, however, cuts were completely trimmed of subcutaneous and accessible intermuscular fat and a single equation that was validated for total carcass retail product yield also was used to predict each cut yield on a weight basis. The equation contained HCW as an independent variable, the samples size was much smaller (n=66), and the sample population was much more homogeneous for carcass traits.

IMPLICATIONS

The ability of single-component and dual-component equations to predict yields of lean trimmings, fat, bone, and several primal and subprimal cuts, with reasonable accuracy and precision using the development dataset, yet low accuracy and precision using the validation dataset, suggests that the VIA systems tested in this study do not have the potential as tool for more sensitive carcass segregation at this time. Further investigation to elucidate the full potential of dual-component primal and subprimal cut yield prediction, perhaps looking at a sample population with greater variance (i.e., equal numbers of YG 1s, 2s, 3s, 4s, and 5s for equation development) and having VPS 2000 images available from each primal interface to provide independent variables representative of the entire carcass, is justifiable.

Table 1. Number of carcass sides[a] included in the study stratified by hot carcass weight class and yield grade[b]

	Single-Component[c]					Dual-Component[c]				
	Development		Validation			Development		Validation		
Yield grade	Light[d]	Heavy[e]	Light[d]	Heavy[e]	Total (Development / Validation)	Light[d]	Heavy[e]	Light[d]	Heavy[e]	Total (Development / Validation)
1	6	14	2	2	20/4	5	12	2	2	17/4
2	12	38	5	17	50/22	11	37	5	17	48/22
3	9	37	3	26	46/29	9	31	3	25	40/28
4	4	14	-	2	18/2	4	14	-	1	18/1
5	1	7	-	1	8/1	-	6	-	1	6/1
Total	32	110	10	48	142/58	29	100	10	46	129/56

[a] Carcass sides = left-side; All dual-component carcasses are also represented in single-component carcasses.

[b] Yield grade = expert yield grade (nearest 10th) calculated by USDA off-line determined factors and instrument measured ribeye area.

[c] Single-Component = carcasses evaluated by the VBG 2000; Dual-Component = carcasses evaluated by the VBG 2000 and VPS 2000.

[d] Light = hot carcass weight < 341 kg.

[e] Heavy = hot carcass weight ≥ 341 kg.

Table 2. Descriptive statistics for carcass traits and USDA yield grades

Item	Development					Validation				
	n	Mean	SD	Minimum	Maximum	n	Mean	SD	Minimum	Maximum
Single-component[a]										
Hot carcass weight, kg[b]	142	366.40	38.31	276.82	473.18	58	366.79	30.62	293.18	433.18
Chilled carcass-side weight, kg[c]	142	181.61	19.41	135.54	239.78	58	182.16	14.96	145.24	214.41
Yield grade, nearest 10th, [b]	142	3.08	1.05	0.52	5.85	58	3.00	0.77	0.75	5.64
Adjusted fat thickness, cm[b]	142	1.40	0.73	0.00	3.56	58	1.36	0.48	0.30	2.44
Longissimus muscle area, cm^2, [b]	142	86.23	10.31	58.45	114.13	58	87.12	9.29	65.74	111.87
Kidney, pelvic, and heart fat, %[b]	142	2.09	0.50	0.50	3.50	58	2.07	0.48	1.00	3.00
Online yield grades, whole number	142	2.60	0.96	1.00	5.00	58	2.40	0.86	1.00	5.00
Dual-component[a]										
Hot carcass weight, kg[b]	129	363.32	35.81	276.82	465.45	56	366.43	30.77	293.18	433.18
Chilled carcass-side weight, kg[c]	129	180.54	17.90	135.54	232.06	56	182.17	15.17	145.24	214.41
Yield grade, nearest 10th, [b]	129	3.04	1.03	0.52	5.75	56	2.96	0.75	0.75	5.64
Adjusted fat thickness, cm[b]	129	1.41	0.73	0.00	3.56	56	1.34	0.47	0.30	2.44
Longissimus muscle area, cm^2, [b]	129	86.62	9.79	65.23	114.13	56	87.42	9.23	65.74	111.87
Kidney, pelvic, and heart fat, %[b]	129	2.08	0.48	0.50	3.50	56	2.05	0.47	1.00	3.00
Online yield grades, whole number	129	2.62	0.95	1.00	5.00	56	2.38	0.86	1.00	5.00

[a] Single-component = carcasses associated with VBG 2000 equations; Dual-component = carcasses associated with VBG 2000 and VPS 2000 equations; all carcasses represented in the VPS 2000 output are also represented in the VBG 2000 output.

[b] Yield grade, nearest 10th calculation factors: actual hot carcass weight; USDA grader off-line determined adjusted fat thickness and KPH %; instrument measured ribeye area.

[c] Chilled carcass side weight, left-side.

Table 3. Independent variables, C_p, R^2, root mean square error (RMSE), and partial R^2 for regression equations using 12th/13th rib interface single component system (VBG 2000) factors to predict percent yields of primal or subprimal cuts

		Development					Validation
Dependent variable[a]	Variables in model[b]	C_p	R^2	RMSE	β Coefficient	Partial R^2	R^{2*}
Lean trimmings[c]	A_00616	6.34	0.3611	0.94	0.0002195	0.0372	-0.2320
	A_06390				-0.0016	0.0870	
	A_08209				0.45195	0.0551	
	S_04657				0.00601	0.0388	
	S_04729				-0.00739	0.0456	
	S_09129				0.83816	0.0418	
	RibEyeBroad_mm				-0.05304	0.0282	
	REA_Inch2				2.3936	0.1641	
	RibEyeArea				-0.00284	0.1535	
Fat[c]	Quality	4.74	0.7715	1.92	-45.16913	0.6159	-0.3838
	GradientVert				-0.00553	0.0184	
	A_05514				0.00026242	0.0134	
	GradientHori				0.00354	0.0077	
	Check1				3.7059	0.0073	
	RibEyeBroad_mm				0.10355	0.0228	
Bone[c]	RibEyeArea	0.40	0.7331	1.18	-0.00104	0.1107	-0.4361
	NumberFatPieces				0.0043	0.0143	
	RibEyeHeight_mm				0.06091	0.0313	
	Quality				23.60943	0.5686	
Square cut chuck (IMPS, 113)	RibEyeArea23	4.67	0.3864	0.89	-0.00114	0.0359	0.1081
	RibEyeFat12				0.00544	0.0635	
	TotalAreaPixel				0.00024315	0.0287	
	PYG				1.65905	0.0358	
	ADJ				-3.3699	0.0838	
	IA_11				-0.00597	0.0225	
	A_00616				-0.00020522	0.0294	
	A_06390				0.00114	0.1187	
	RibEyeBroadPixel				-0.00596	0.0154	
	L_Star				0.04639	0.0134	

Brisket (IMPS 120, PSO 1)	RibEyeHeightPixel	3.88	0.1674	0.36	0.10892	0.0486	0.0435
	TotalAreaPixel				-0.00134	0.0485	
	PYGFatArea				-2.51721	0.0491	
	PYG				30.43516	0.0495	
	S_05875				0.0015	0.0409	
	REA_Inch2				0.07145	0.0247	
Brisket (IMPS 120, PSO 3)	RibEyeFat12	4.77	0.1627	0.35	-0.00241	0.0282	0.0539
	RibEyeFat23				0.00397	0.0141	
	NumberFatPiecesCorrected23				0.0078	0.0235	
	TotalMeatPixel				0.00007997	0.0817	
	RibEyeColor_g				0.3948	0.0344	
	L_Star				-1.1521	0.0360	
Brisket flat (IMPS 120A)	RibEyeBroadPixel	9.24	0.3222	0.15	0.00143	0.0770	-0.1163
	Marb				-0.00238	0.0741	
	A_02491				0.02824	0.0552	
	A_06033				-0.26943	0.0351	
	A_08269				0.05	0.0259	
	A_14087				-0.02413	0.0194	
	A_17073				-0.13373	0.1163	
	S_01991				0.00265	0.0450	
Brisket point (IMPS 120B)	TotalAreaPixel	6.74	0.1800	0.15	-0.00031767	0.0471	0.1348
	TotalMeatPixel				0.00033101	0.0507	
	TotalFatPixel				0.00039016	0.0513	
	Calc_YG				-0.16518	0.0412	
Chuck roll (IMPS 116A)	NumberFatPieces12	3.00	0.2732	0.71	-0.03441	0.0432	-0.0907
	NumberFatPiecesCorrected				-0.00558	0.0296	
	NumberFatPiecesCorrected13				0.02256	0.0375	
	RibEyeHeightPixel				-0.01019	0.1137	
	GradientVert12				0.00508	0.0456	
	GradientVert23				-0.00462	0.0217	
	ADJ				-0.31406	0.0380	
	A_13388				0.00071318	0.0652	

Mock tender (IMPS 116B)	Quality	2.28	0.5232	0.06	0.71193	0.3157	-0.4506
	RibEyeColor_r				-0.00293	0.0675	
	A_08209				-0.02354	0.0317	
	A_17073				-0.04696	0.0333	
	S_04729				0.00019472	0.0528	
	L_Star				0.00572	0.0302	
	RibEyeAreaFatCorrected				0.00034893	0.0472	
	RibEyeArea				-0.00001113	0.0192	
Clod (IMPS 114C, PSO 3)	NumberFatPieces	7.05	0.4460	0.34	-0.05927	0.0144	0.0986
	NumberFatPieces13				-0.00623	0.0446	
	NumberFatPiecesCorrected				0.06363	0.0160	
	TotalAreaPixel				0.00006088	0.0344	
	TotalFatPixel				-0.00017584	0.1321	
	A_08209				-0.06055	0.0284	
	S_14105				0.00252	0.0500	
Chuck eye roll (IMPS 116D, PSO 6)	TotalFatPixel	9.48	0.2759	0.41	-0.00011482	0.1495	0.1069
	Marb				0.00336	0.0314	
	A_05514				-0.00010856	0.0519	
	A_08209				0.14107	0.0309	
	A_10553				0.16001	0.0164	
	A_14087				0.0897	0.0319	
	S_04729				-0.00119	0.0153	
	S_05118				4.81E-10	0.0238	
	S_10553				-0.00401	0.0301	
Underblade (IMPS 116E)	A_06033	0.76	0.1549	0.34	0.43694	0.0579	-1.2081
	A_08269				-0.1051	0.0818	
	S_10553				0.00045066	0.0136	
Boneless short ribs (IMPS 130)	PYGFatArea	7.10	0.4154	0.16	-0.0655	0.0723	0.0422
	PYG				0.70305	0.0769	
	Marb				-0.0018	0.0686	
	A_05514				0.00002817	0.0434	
	S_03505				0.00097717	0.1629	
	S_05875				-0.00195	0.1273	

Short plate (IMPS 121)	NumberFatPiecesCorrected	4.40	0.3953	0.36	-0.00428	0.0828	0.0254
	NumberFatPiecesCorrected12				0.01672	0.0619	
	GradientHori12				-0.00112	0.0151	
	PYG				0.18779	0.0670	
	IA_11				0.00373	0.0536	
	A_00616				-0.00007622	0.0655	
Boneless short ribs (IMPS 123D)	L_Star	3.68	0.4596	0.11	0.00821	0.0322	0.2673
	GradientHori				-0.00008488	0.0369	
	Quality				-1.22676	0.3239	
	REA_Inch2				0.01857	0.0293	
Ribeye (IMPS 112A, PSO 3, 5.1 x 5.1 cm lip-on)	HCW	1.69	0.3075	0.20	-0.00077175	0.0638	0.1181
	RibEyeArea				0.00008093	0.1325	
	RibEyeColor				-0.00917	0.0319	
	A_06045				-0.4964	0.0666	
Outside skirt (IMPS 121C)	RibEyeFat23	6.11	0.1433	0.08	0.00141	0.0241	-0.1685
	NumberFatPieces23				-0.04709	0.0031	
	NumberFatPiecesCorrected23				0.04204	0.0024	
	GradientVert23				0.00060201	0.0644	
	A_06390				-0.00002659	0.0169	
	A_10553				-0.00042664	0.0113	
	REA_Inch2				-0.00861	0.0189	
Inside skirt (IMPS 212D)	REMarb	9.91	0.1620	0.13	0.00148	0.0708	-0.0926
	IA_11				-0.00084329	0.0242	
	A_00187				0.03012	0.0386	
	A_02491				-0.02701	0.0379	
	A_06045				0.41477	0.0320	
	A_08209				0.06072	0.0680	
	S_07119				-0.04979	0.0423	
	S_07921				-0.14229	0.0686	
Rib cap (IMPS 112D)	HCW	8.88	0.6993	0.24	-0.00102	0.0342	0.4589

	RibEye_MF				0.2051	0.0188	
	RibEyeFat				0.0025	0.0154	
	TotalFatPixel				0.00012624	0.0342	
	Marb				0.00157	0.0224	
	A_17073				0.15498	0.0204	
	S_04729				-0.00082108	0.0194	
	S_05875				0.001	0.0073	
	PYG				0.14907	0.0080	
Loin (IMPS 172)	RibEyeHeightPixel	10.36	0.5629	1.00	-0.32817	0.0296	0.1156
	TotalAreaPixel				0.00408	0.0307	
	PYGFatArea				7.43004	0.0291	
	RibEyeColor				11.18216	0.0430	
	RibEyeColor_r				-4.41741	0.0436	
	A_08209				-0.44909	0.0579	
	A_08269				0.22049	0.0422	
	PYG				-89.8764	0.0292	
	ADJ				1.67315	0.0259	
Striploin (IMPS 180, PSO 3, 2.54 cm x 2.54 cm lip-on)	HCW	4.52	0.4940	0.18	-0.00071	0.0463	-0.1068
	RibEyeArea23				0.00028	0.0252	
	Marb				-0.00244	0.0446	
	A_06033				-0.51553	0.0313	
	A_08209				-0.03552	0.0175	
	S_01423				0.00209	0.0466	
	S_07119				0.05263	0.0122	
	S_07766				0.00000	0.0140	
	check1				-0.74749	0.0654	
	RibEyeArea				0.00006	0.0121	
Top sirloin butt (IMPS 184)	RibEyeColor_b	4.42	0.3334	0.30	-0.00971	0.0641	-0.1503
	Marb				0.00158	0.0389	
	A_02491				-0.04182	0.0791	
	PYG				0.23481	0.2100	
Bottom sirloin butt (IMPS 185)	HCW	5.47	0.3241	0.42	-0.00085181	0.0198	-0.0776

	NumberFatPieces				0.00389	0.0383	
	Quality				-3.40067	0.1565	
	GradientHori				-0.00161	0.0884	
	GradientVert12				0.00146	0.0509	
	S_04657				-0.00058615	0.0498	
Bottom sirloin butt, flap (IMPS 185A)	HCW	3.45	0.3689	0.10	0.00039842	0.0636	-0.1646
	RibEyeArea				-0.00011651	0.0714	
	RibEyeArea13				0.00017904	0.0880	
	RibEyeFat12				-0.00041622	0.0133	
	NumberFatPieces12				0.00527	0.0390	
	NumberFatPiecesCorrected				0.00176	0.0966	
	NumberFatPiecesCorrected13				-0.0037	0.0411	
Ball tip (IMPS 185B)	NumberFatPieces	6.86	0.1003	0.22	0.00114	0.0211	-0.2123
	GradientHori				-0.00039114	0.0332	
	GradientVert13				-0.00087056	0.0399	
	GradientVert12				0.00154	0.0602	
	RibEyeHeight_mm				-0.1647	0.0388	
	RibEyeHeightPixel				0.05995	0.0384	
	GradientHori				-0.0002133	0.0283	
	ADJ				-0.04985	0.0402	
Tri tip (IMPS 185D)	HCW	3.17	0.3001	0.07	-0.00042503	0.1465	0.1229
	RibEyeArea				0.00001835	0.0447	
	RibEyeAreaFatCorrected				0.00055999	0.0333	
	RibEyeAreaFatCorrected13				-0.00074056	0.0369	
	Quality				0.27617	0.0477	
Tenderloin (IMPS 189A)	Marb	2.89	0.4165	0.11	-0.00095352	0.0571	0.5002
	S_01423				0.00108	0.0758	
	S_05875				-0.0015	0.1400	
	check1				-0.18262	0.0120	
	REA_Inch2				-0.13676	0.0350	
	RibEyeArea				0.00019365	0.0402	
	ADJ				-0.13019	0.1542	

Flank primal, untrimmed	RibEyeArea12	2.25	0.3464	0.32	-0.00020662	0.0605	-0.0046
	RibEyeBlue23				0.0041	0.0275	
	ADJ				0.24006	0.1244	
	L_Star				0.02291	0.0348	
	check1				0.74471	0.0300	
	RibEyeBroad_mm				0.01112	0.0230	
	HCW				-0.000566	0.0127	
Round, primal (IMPS 158)	NumberFatPieces13	4.41	0.6428	0.92	-0.01955	0.0255	-0.0541
	A_05514				-0.000261	0.0454	
	S_04657				0.00122	0.0106	
	S_05118				1.99E-09	0.0382	
	GradientHori				0.00197	0.0183	
	Quality				12.51532	0.3255	
	RibEyeBroad_mm				-0.03538	0.0182	
	RibEyeAreaFatCorrected				0.0037	0.0071	
Knuckle (IMPS 167)	NumberFatPieces23	6.13	0.3366	0.31	-0.01744	0.0690	-0.2267
	S_04657				0.00038967	0.0376	
	L_Star				0.02536	0.0463	
	NumberFatPieces				-0.00207	0.0201	
	GradientHori				0.00134	0.0960	
	Quality				2.22718	0.1111	
Round, inside, cap off (IMPS 169A)	GradientHori13	7.45	0.5641	0.29	-0.00351	0.0358	0.4027
	GradientHori12				0.00427	0.0341	
	Calc_YG				-0.58593	0.0403	
	ADJ				1.75975	0.0988	
	A_05514				-0.00004485	0.0399	
	Quality				2.44691	0.0146	
	HCW				-0.00073008	0.0159	
	PYG				-0.76846	0.0559	
Gooseneck, heel out (IMPS 170A)	RibEyeArea13	8.20	0.4070	0.42	0.0003979	0.2103	-0.0622
	A_05514				-0.0001028	0.0554	
	A_13388				0.00112	0.1235	
	S_01991				-0.00487	0.0394	

	S_07921				-0.50958	0.0404	
	S_09129				0.36147	0.0368	
	HCW				-0.00090849	0.0177	
Knuckle, peeled (IMPS 167A)	NumberFatPieces	4.42	0.4245	0.26	-0.00247	0.0318	-0.3032
	NumberFatPieces23				-0.01378	0.0400	
	Quality				2.25619	0.1419	
	GradientHori				0.00122	0.0760	
	A_06390				-0.00011565	0.0192	
	A_13388				0.00036619	0.0425	
	S_04657				0.00184	0.0430	
	S_04729				-0.00157	0.0291	
Outside flat (IMPS 171B, PSO 3)	NumberFatPiecesCorrected12	4.87	0.4178	0.30	-0.00707	0.0491	0.2173
	A_13388				0.00074816	0.1972	
	S_04729				-0.00088237	0.1380	
	NumberFatPieces				0.00244	0.0306	
	check1				-0.95218	0.0470	
	Quality				-3.51118	0.0397	
	REA_Inch2				0.10213	0.0789	
	HCW				-0.00059892	0.0134	
	ADJ				-0.33645	0.0344	
Eye of round (IMPS 171C, PSO 6)	TotalMeatPixel	8.02	0.4630	0.13	-0.00010969	0.1168	-0.1396
	Marb				0.00104	0.0518	
	A_06390				-0.00014207	0.0695	
	A_13388				0.00025097	0.0772	
	S_10553				-0.00026964	0.0349	
	RibEyeBroadPixel				0.01519	0.0180	
	check1				-0.361	0.0326	
	RibEyeBroad_mm				-0.0803	0.0191	
	REA_Inch2				0.15626	0.2275	
Heel (IMPS 171F)	HCW	4.58	0.4729	0.10	-0.00029292	0.0283	0.0914
	RibEyeArea12				0.00007164	0.0170	
	TotalAreaPixel				-0.00003028	0.1707	
	GradientVert23				-0.00033253	0.0421	

Marb	0.00105	0.0376
A_05514	-0.00002908	0.0451
A_13388	0.00014536	0.0472
S_03505	-0.00032764	0.0272
S_05118	2.60E-10	0.0499

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[a] Dependent variables predicted as a percent of the aggregate chilled left carcass side weight.

[b] Variables in model derived from VBG 2000 factors are presented as actual names, but undefined per technology provider's request.

[c] Lean trimmings, fat, and bone are the collective proportional-inverse byproducts of the manufactured primal and subprimal cuts.

[*] Validation R^2 = estimated adjusted R^2 (i.e., the proportion of variability in actual validation yields explained by regression equations from development data).

Table 4. Independent variables, C_p, R^2, root mean square error (RMSE), and partial R^2 for dual-component regression equations using 12th rib surface image (VBG 2000) and loin surface image (VPS 2000) factors to predict percent yields of primal or subprimal cuts

		Development					Validation
Dependent variable[a]	Variables in model[b]	C(p)	R^2	RMSE	β Coefficient	Partial R^2	R^{2*}
Lean trimmings[c]	REA_06390	-2.607	0.4317	0.85367	-0.00103	0.09654	-0.2114
	RES_04657				0.00113	0.01768	
	RES_09129				0.70439	0.03467	
	RENumberFatPieces				0.00327	0.03664	
	REQuality				4.79664	0.07021	
	1/v5.4*gt12				32852821	0.07776	
	1/v8.2*gt13				77179542	0.01943	
	v2.2				-0.00219	0.08314	
	v1.0*gt				0.00032514	0.08599	
	v2.2/gt				1.71911	0.08248	
	1/v1.3*gt				-783493134	0.08615	
Fat[c]	REQuality	3.1627	0.8137	1.68946	-34.00507	0.20271	-0.4649
	REGradientVert				-0.00598	0.02229	
	REA_05514				0.00038899	0.02379	
	RERibEyeBroadPixel				-0.17729	0.00454	
	RERibEyeHeight_mm				-0.04751	0.00695	
	REGradientHori				0.00446	0.01262	
	REcheck1				4.20098	0.008	
	RERibEyeBroad_mm				1.02249	0.00572	
	1/v5.4*gt12				73529684	0.02146	
	1/v0.3				1274206	0.01596	
	1/v5.1				4332.63658	0.03242	
	1/v5.3				-1994217	0.0209	
	1/v0.3*gt				-1177669838	0.01815	
Bone[c]	RERibEyeArea	-1.7777	0.7721	1.08496	-0.00114	0.10828	-0.4059
	RENumberFatPieces				0.00434	0.01532	
	RERibEyeHeight_mm				0.05891	0.02325	
	REQuality				23.83563	0.53256	
	v3.3*gt				3.84E-08	0.01109	
	1/v0.3				89284	0.01151	

Square cut chuck (IMPS, 113)	RERibEyeFat12	18.3826	0.5974	0.72674	0.0013	0.00943	-0.1332
	RERibEyeBroad_mm				-0.02658	0.02036	
	v2.2*gt				0.00000109	0.03985	
	v4.0*gt				-0.00122	0.10617	
	v4.3*gt13				0.00002293	0.01642	
	v2.3*gt23				0.00000567	0.0347	
	v3.4/gt				-0.24031	0.02857	
	v6.2/gt				-0.51327	0.02481	
	v7.0/gt12				-60.47985	0.16241	
	v3.0/gt13				28.21817	0.15658	
	1/v0.4				-8401435	0.06721	
	1/v3.3				1059459	0.01558	
	1/v4.1				7891.44356	0.12122	
	1/v2.3*gt				-1317852822	0.03445	
	1/v3.3*gt				-1327159262	0.02941	
	1/v4.4*gt				2950618568	0.11845	
	1/v5.2*gt				-34536628	0.0588	
	1/v7.1*gt				11111420	0.17697	
	1/v0.4*gt12				356352629	0.06396	
	1/v2.3*gt12				60147766	0.04625	
	1/v3.1*gt12				-590099	0.14791	
	1/v0.4*gt13				-2.98E+10	0.0443	
	1/v1.0*gt13				396138	0.05796	
	1/v8.2*gt13				7642291535	0.06863	
	1/v8.2*gt23				-2791425852	0.08195	
	1/v8.3*gt23				-4116945931	0.0964	
Brisket (IMPS 120, PSO 1)	RES_10553	19.8653	0.5457	0.27393	0.00026728	0.01757	-0.1175
	RERibEyeBroad_mm				0.00653	0.01004	
	v3.4				0.00010432	0.02827	
	v6.1				-0.21415	0.05386	
	v8.4				-0.00020662	0.07162	
	v3.0*gt13				-0.01912	0.06907	
	v4.2/gt12				0.01497	0.09538	
	1/v3.3				340717	0.05946	
	1/v6.4				842914	0.08767	
	1/v8.0				257.97015	0.14631	

	1/v8.2				-756054	0.1752	
	1/v2.4*gt				-1037786127	0.03501	
	1/v3.2*gt				-155003747	0.02958	
	1/v4.0*gt				422124	0.07046	
	1/v7.1*gt				360885	0.03951	
	1/v8.2*gt				-303581132	0.05838	
	1/v4.1*gt12				-52273	0.10927	
	1/v6.3*gt12				-16101963	0.06775	
	1/v8.2*gt12				27821238	0.09736	
	1/v1.1*gt13				3128314	0.06016	
	1/v4.0*gt13				-3924025	0.07354	
	1/v2.4*gt23				2875212164	0.04616	
	1/v3.2*gt23				478987865	0.03029	
Brisket (IMPS 120, PSO 3)	RERibEyeFat12	25.0896	0.5734	0.27604	-0.0016	0.01245	-0.0303
	RERibEyeFat23				0.00539	0.02038	
	RERibEyeColor_g				0.34697	0.02089	
	RECalc_YG				-0.08211	0.02298	
	REL_Star				-1.0066	0.02165	
	v4.1				-0.21767	0.05863	
	v8.2/gt				-0.09699	0.0208	
	v1.3/gt12				-0.00553	0.03961	
	v5.3/gt13				0.00182	0.03709	
	v2.0/gt23				-15.92045	0.01047	
	1/v2.3				-1732935	0.16144	
	1/v2.4				2058655	0.12899	
	1/v8.3				-181434	0.03973	
	1/v0.1*gt				-2243968	0.03953	
	1/v2.3*gt				1130054752	0.08483	
	1/v6.0*gt				-455558	0.07593	
	1/v6.4*gt				-1342370505	0.08743	
	1/v7.1*gt				1884205	0.06587	
	1/v2.1*gt12				49253	0.02971	
	1/v7.1*gt13				-16668918	0.05831	
	1/v0.1*gt23				6763613	0.03849	
	1/v3.0*gt23				54882	0.16622	
	1/v4.1*gt23				-2846239	0.05321	

	1/v5.0*gt23				-35027	0.02384	
	1/v6.0*gt23				1321419	0.07162	
	1/v8.1*gt23				1711936	0.02778	
Brisket flat (IMPS 120A)	RERibEyeFat12	25.0896	0.5734	0.27604	-0.0016	0.01245	-0.2075
	RERibEyeFat23				0.00539	0.02038	
	RERibEyeColor_g				0.34697	0.02089	
	RECalc_YG				-0.08211	0.02298	
	REL_Star				-1.0066	0.02165	
	v4.1				-0.21767	0.05863	
	v8.2/gt				-0.09699	0.0208	
	v1.3/gt12				-0.00553	0.03961	
	v5.3/gt13				0.00182	0.03709	
	v2.0/gt23				-15.92045	0.01047	
	1/v2.3				-1732935	0.16144	
	1/v2.4				2058655	0.12899	
	1/v8.3				-181434	0.03973	
	1/v0.1*gt				-2243968	0.03953	
	1/v2.3*gt				1130054752	0.08483	
	1/v6.0*gt				-455558	0.07593	
	1/v6.4*gt				-1342370505	0.08743	
	1/v7.1*gt				1884205	0.06587	
	1/v2.1*gt12				49253	0.02971	
	1/v7.1*gt13				-16668918	0.05831	
	1/v0.1*gt23				6763613	0.03849	
	1/v3.0*gt23				54882	0.16622	
	1/v4.1*gt23				-2846239	0.05321	
	1/v5.0*gt23				-35027	0.02384	
	1/v6.0*gt23				1321419	0.07162	
	1/v8.1*gt23				1711936	0.02778	
Brisket point (IMPS 120B)	RERibEyeBroadPixel	29.7973	0.5223	0.12773	0.00062244	0.0122	-0.4765
	REGradientVert				0.00018011	0.02616	
	REGradientVert23				-0.00056048	0.02001	
	v2.1*gt13				-0.05508	0.04587	
	v7.0*gt13				-0.00376	0.05863	
	v2.0/gt				-840.65747	0.07106	
	v2.1/gt				-318.26625	0.0785	

	v2.2/gt				4.34911	0.05655	
	v4.1/gt12				-0.3711	0.01806	
	v2.2/gt23				-0.4415	0.05183	
	1/v0.2				-263000	0.03447	
	1/v1.3				838714	0.08286	
	1/v2.3				-583848	0.08009	
	1/v8.3				-51676	0.05133	
	1/v0.1*gt				-1003253	0.03356	
	1/v1.3*gt				-584554537	0.06012	
	1/v2.3*gt				454528862	0.07285	
	1/v6.1*gt				-86902382	0.06043	
	1/v0.2*gt12				12247712	0.0371	
	1/v5.4*gt12				-39269177	0.06639	
	1/v6.0*gt12				-6665.24078	0.0637	
	1/v6.2*gt12				2902372	0.05554	
	1/v0.2*gt13				-1266529246	0.03991	
	1/v0.1*gt23				3019422	0.03276	
	1/v1.4*gt23				3149532927	0.05698	
	1/v6.0*gt23				612588	0.06815	
	1/v6.3*gt23				236640432	0.05549	
Chuck roll (IMPS 116)	RERibEyeHeightPixel	26.4421	0.6285	0.52607	-0.00446	0.01649	-0.2885
	REA_13388				0.00039669	0.01712	
	Konlen				-0.00067539	0.03236	
	v6.3				0.00060968	0.07728	
	v0.2*gt				-3.02E-08	0.01715	
	v4.1*gt				0.00095939	0.14455	
	v2.1*gt13				-0.17487	0.12132	
	v4.4/gt				0.77159	0.11015	
	v8.3/gt				-0.83648	0.11375	
	v7.3/gt12				-0.00954	0.02154	
	v1.0/gt13				19.12499	0.15948	
	v2.0/gt13				-14.50116	0.11677	
	v3.2/gt13				-0.00843	0.09228	
	v5.1/gt13				13.13573	0.11032	
	1/v3.4				-1026907	0.03247	
	1/v8.2				-36463	0.06366	

	1/v5.3*gt				-121799857	0.02349	
	1/v7.1*gt				8286479	0.1659	
	1/v1.1*gt12				-383308	0.16034	
	1/v2.3*gt12				16393318	0.07831	
	1/v4.1*gt12				245590	0.20255	
	1/v5.1*gt12				255507	0.13017	
	1/v7.1*gt12				-277761	0.17018	
	1/v4.3*gt13				-1.41E+10	0.12441	
	1/v8.1*gt13				-65301777	0.22736	
	1/v8.3*gt13				18826179162	0.12175	
Mock tender (IMPS 116B)	REQuality	8.598	0.5771	0.05662	0.60634	0.14398	0.2461
	RERibEyeColor_r				-0.00278	0.05102	
	RERibEyeColor_g				0.00246	0.03295	
	REA_08209				-0.02248	0.02499	
	REA_17073				-0.05376	0.03674	
	RES_04729				0.00021342	0.0516	
	RERibEyeAreaFatCorrected				0.00025616	0.02399	
	RERibEyeArea				-0.00001149	0.0161	
	1/v4.1				-14.69752	0.02264	
	1/v1.4*gt12				469942	0.01652	
	1/v4.4*gt12				-616387	0.0201	
Clod (IMPS 114C, PSO 3)	RENumberFatPieces13	25.0483	0.6826	0.27975	-0.00304	0.00814	-1.2838
	RENumberFatPiecesCorrected				0.00291	0.0184	
	RETotalFatPixel				-0.0000632	0.02793	
	REIA_11				0.00228	0.03649	
	REA_08209				-0.05805	0.02004	
	v0.4				-0.00066562	0.04555	
	v0.4*gt				-9.46E-07	0.03225	
	v0.4*gt23				0.00001622	0.03776	
	v7.0/gt				314.8886	0.03496	
	v7.2/gt				-0.48577	0.0396	
	v8.1/gt				290.65733	0.11959	
	v8.4/gt13				0.0012	0.05908	
	1/v4.2				89481	0.05656	
	1/v0.0*gt				-1009932	0.0552	
	1/v0.2*gt				554403181	0.02018	

	1/v4.0*gt				-581490	0.03171	
	1/v7.3*gt				-214646467	0.02718	
	1/v8.0*gt				-46951	0.06658	
	1/v8.1*gt				1253124	0.10945	
	1/v0.1*gt12				-59777	0.09128	
	1/v0.4*gt13				-2.50E+10	0.09456	
	1/v0.0*gt23				2752248	0.04436	
	1/v0.2*gt23				-1424314317	0.01378	
	1/v0.3*gt23				4822760950	0.08607	
	1/v4.0*gt23				1445270	0.02702	
	1/v5.2*gt23				11573927	0.00914	
Chuck eye roll (IMPS 116D, PSO 6)	RETotalFatPixel	17.0856	0.5012	0.33885	-0.0000584	0.03411	-0.0747
	REGradientHori23				0.00046604	0.0102	
	v6.2*gt				-7.11E-07	0.04053	
	v6.2/gt				0.65667	0.02331	
	v7.2/gt12				-0.00277	0.11844	
	1/v1.0				1124.58491	0.08976	
	1/v2.1				3166.94723	0.07205	
	1/v2.3				-1155373	0.0731	
	1/v6.0				-633.46732	0.0755	
	1/v6.0*gt				529118	0.08019	
	1/v6.3*gt				940476198	0.08064	
	1/v1.0*gt12				-50460	0.09666	
	1/v6.2*gt12				6853532	0.07281	
	1/v1.0*gt13				4829751	0.10688	
	1/v6.2*gt13				-1862950168	0.08365	
	1/v6.1*gt23				-8967429	0.07509	
Underblade (IMPS 116E)	REA_05514	27.1145	0.7889	0.21167	-0.00003275	0.01652	-4.4144
	REA_08209				0.0885	0.02467	
	RES_04657				0.00206	0.02835	
	RES_04729				-0.00254	0.03414	
	v4.3*gt				8.45E-07	0.21673	
	v0.4*gt13				-0.00006152	0.26708	
	v8.0*gt13				0.13449	0.21239	
	v7.0*gt23				0.00123	0.01922	
	v0.4/gt				0.45358	0.26613	

	v8.2/gt				-1.52213	0.21288	
	1/v5.0				-84.91075	0.07619	
	1/v5.1				-3508.54198	0.04962	
	1/v7.3				-1548950	0.14565	
	1/v8.2				399734	0.22998	
	1/v4.1*gt				1781836	0.18024	
	1/v7.2*gt				191609326	0.097	
	1/v1.0*gt12				1237.73601	0.04386	
	1/v1.1*gt12				207850	0.10447	
	1/v3.0*gt12				-2058.9848	0.07516	
	1/v7.2*gt12				-4628816	0.03923	
	1/v3.3*gt13				-1.65E+10	0.07609	
	1/v1.1*gt23				-16927971	0.08873	
	1/v3.3*gt23				5065237019	0.07914	
	1/v5.1*gt23				6446480	0.02825	
	1/v6.2*gt23				-33214504	0.17861	
	1/v7.3*gt23				3195071140	0.13822	
	1/v8.0*gt23				-1595319	0.20194	
	1/v8.4*gt23				-3221570348	0.13613	
Boneless short ribs (IMPS 130)	RES_05875	19.7734	0.6209	0.13637	-0.00133	0.03176	-0.4805
	REMarb				0.00228	0.04872	
	REA_06033				0.32827	0.03021	
	REA_08209				0.09786	0.09902	
	REA_08269				-0.07498	0.02297	
	REA_10553				0.10065	0.03323	
	RES_10553				-0.00201	0.04088	
	v7.2*gt				4.19E-07	0.06872	
	v8.2*gt12				0.00006546	0.04022	
	v7.0*gt13				-0.04337	0.07799	
	v8.2*gt23				-0.00001993	0.03734	
	v3.3/gt13				-0.00148	0.10061	
	1/v3.4				-1227194	0.09504	
	1/v7.3				1184166	0.10088	
	1/v8.3				-487832	0.04245	
	1/v3.3*gt				-279329421	0.05393	
	1/v4.1*gt				-514992	0.05512	

	1/v4.3*gt				392555155	0.06194	
	1/v5.0*gt				-146467	0.03338	
	1/v7.1*gt				1734835	0.06923	
	1/v8.3*gt				678801354	0.02015	
	1/v1.0*gt12				102.49431	0.01205	
	1/v7.1*gt12				-86241	0.06515	
	1/v7.0*gt13				-79042	0.03178	
	1/v8.3*gt13				-5522102641	0.03243	
	1/v5.0*gt23				441117	0.03438	
Short plate (IMPS 121)	RENumberFatPiecesCorrected	12.8411	0.5197	0.32513	-0.00352	0.0498	-0.1461
	RENumberFatPiecesCorrected12				0.01518	0.04633	
	REGradientHori12				-0.00109	0.01341	
	REPYG				0.19759	0.05536	
	REIA_11				0.00303	0.03389	
	REA_00616				-0.0000694	0.04576	
	v6.3				0.00002646	0.01356	
	v5.3/gt12				0.00129	0.01808	
	v8.3/gt12				-0.00165	0.05859	
	v5.4/gt13				-0.00022023	0.00881	
	1/v5.2*gt				-5939597	0.03462	
	1/v6.0*gt13				73180	0.03272	
Boneless short ribs (IMPS 123D)	RERibEyeArea	19.0609	0.6221	0.09945	0.00003097	0.03194	-0.2359
	REL_Star				0.00623	0.01257	
	REGradientHori				-0.00008393	0.0325	
	REQuality				-1.25501	0.19825	
	REHCW				-0.00082253	0.01102	
	v7.0				-0.14656	0.0315	
	v6.0*gt				0.00032657	0.06438	
	v7.3*gt				1.00E-07	0.07152	
	v4.0*gt12				-0.00216	0.05485	
	v4.4*gt12				-0.00001622	0.05055	
	v8.4*gt13				0.00005124	0.04842	
	v4.3/gt				-0.07387	0.05702	
	1/v3.0				-33.16611	0.027	
	1/v3.3				149610	0.06625	
	1/v6.1				-3519.63518	0.07106	

	1/v7.1				914.71531	0.04129	
	1/v3.1*gt				-198249	0.03487	
	1/v6.1*gt				52828648	0.02975	
	1/v3.0*gt12				980.11566	0.02773	
	1/v4.4*gt12				-6047497	0.06191	
	1/v6.1*gt12				63108	0.07624	
	1/v6.2*gt23				-144692681	0.02582	
	1/v6.3*gt23				-90985461	0.07914	
	1/v7.0*gt23				-47368	0.05661	
Ribeye (IMPS 112A, PSO 3, 5.1 cm x 5.1 cm lip-on)	RERibEyeColor	2.5364	0.4032	0.19319	-0.0098	0.03442	0.0847
	REA_06045				-0.61367	0.09016	
	RERibEyeAreaFatCorrected				0.00047013	0.01539	
	RERibEyeArea				0.00009553	0.15126	
	REHCW				-0.00146	0.02107	
	v4.0/gt				-13.5902	0.03234	
	v0.3/gt12				0.00469	0.0494	
	v0.3/gt23				-0.01439	0.04955	
	1/v1.1*gt13				969874	0.03689	
Outside skirt (IMPS 121C)	RERibEyeFat23	26.9097	0.5184	0.07126	0.00289	0.08422	-0.6700
	RENumberFatPieces23				-0.11583	0.01755	
	RENumberFatPiecesCorrected23				0.11365	0.01679	
	RERibEyeAreaFatCorrected				-0.00053878	0.03622	
	v3.3*gt				-5.55E-08	0.02656	
	v7.4*gt				7.72E-08	0.06471	
	v8.0*gt13				0.01569	0.06556	
	v6.0*gt23				-0.00115	0.10621	
	v8.2/gt				0.56345	0.18745	
	v8.2/gt12				-0.02196	0.18917	
	1/v2.0				-91.40631	0.04594	
	1/v4.4				374038	0.0881	
	1/v7.1				996.33932	0.1947	
	1/v8.3				-318296	0.09351	
	1/v2.2*gt				-27363349	0.06349	
	1/v2.4*gt				302253697	0.12203	
	1/v3.3*gt				53873010	0.05714	

	1/v2.0*gt12				2687.24859	0.04718	
	1/v2.2*gt12				987361	0.06418	
	1/v6.4*gt12				-10711857	0.12343	
	1/v3.1*gt13				-2690407	0.08096	
	1/v6.0*gt13				-92557	0.06079	
	1/v7.0*gt13				138155	0.06944	
	1/v7.1*gt13				-5982941	0.14223	
	1/v8.0*gt13				1824048	0.04984	
	1/v3.2*gt23				-10566296	0.07182	
	1/v6.1*gt23				1273429	0.1119	
	1/v8.0*gt23				-591505	0.04807	
Inside skirt (IMPS 212D)	REMarb	9.5719	0.3007	0.12129	0.00122	0.064	-0.1689
	REIA_11				-0.00102	0.03087	
	REA_00187				0.04752	0.08205	
	REA_02491				-0.03349	0.05308	
	REA_08209				0.06017	0.06158	
	RES_07119				-0.02856	0.03065	
	RES_07921				-0.16934	0.09494	
	REPYG				0.02964	0.01415	
	v1.2*gt				1.09E-07	0.06356	
	v5.2*gt				-1.06E-07	0.07682	
	v3.1*gt13				0.00695	0.0804	
	v7.1*gt13				-0.00601	0.07618	
Rib cap (IMPS 112D)	RERibEye_MF	25.424	0.7764	0.22177	0.26658	0.03828	0.2556
	RERibEyeFat				0.00305	0.0275	
	RETotalFatPixel				0.00013307	0.14651	
	REMarb				0.00149	0.023	
	v3.0*gt13				-0.02083	0.03839	
	v4.4/gt				-0.05371	0.02139	
	v8.1/gt13				-2.46305	0.02444	
	1/v1.4				-1592920	0.02828	
	1/v4.2				-9409.01786	0.01873	
	1/v7.2				-59458	0.02352	
	1/v1.1*gt				712328	0.01973	
	1/v3.3*gt				521652219	0.04394	
	1/v8.2*gt				283507074	0.0215	

	1/v1.4*gt12				66270281	0.03912	
	1/v8.1*gt12				-14403	0.00539	
	1/v1.3*gt13				-4686035795	0.0341	
	1/v5.0*gt13				-3102632	0.01284	
	1/v7.2*gt13				418077143	0.02024	
	1/v7.4*gt13				11899306361	0.01213	
	1/v8.2*gt13				-2365589469	0.01871	
	1/v8.3*gt13				11062283818	0.026	
	1/v0.0*gt23				16436	0.01441	
	1/v3.4*gt23				-5762232857	0.02089	
	1/v5.0*gt23				1014048	0.0128	
	1/v8.3*gt23				-4338994463	0.03392	
Loin (IMPS 172)	RERibEyeHeightPixel	20.2937	0.6605	0.8759	-0.34001	0.03152	-3.4193
	RETotalAreaPixel				0.00423	0.03283	
	REPYGFatArea				7.73762	0.03134	
	RERibEyeColor				11.33057	0.04664	
	RERibEyeColor_r				-4.46264	0.04698	
	REA_08209				-0.30056	0.02511	
	REA_08269				0.13783	0.01542	
	REPYG				-92.31713	0.03076	
	v2.2*gt				-0.00000185	0.03277	
	v0.3*gt13				-0.00000244	0.00736	
	v0.4/gt				0.02985	0.02529	
	v3.2/gt13				0.06126	0.05258	
	v2.2/gt23				0.08969	0.01659	
	v3.2/gt23				-0.5651	0.05219	
	1/v6.1*gt12				24764	0.06379	
Striploin (IMPS 180, PSO 1, 2.54 cm x 2.54 cm lip-on)	RERibEyeArea23	17.7018	0.6360	0.1534	0.00034495	0.13148	-0.4290
	REMarb				-0.00182	0.02336	
	REA_06033				-0.51839	0.03182	
	REA_08209				-0.04717	0.03005	
	RES_01423				0.00179	0.03236	
	RES_07119				0.07049	0.02276	
	RES_07766				-1.83E-07	0.02578	
	REcheck1				-0.24994	0.00689	

	REPYG				0.08285	0.03697	
	v7.2/gt13				-0.00026095	0.03271	
	1/v3.0				130.91792	0.02172	
	1/v2.1*gt				76178	0.0424	
	1/v5.2*gt				44415964	0.03018	
	1/v2.3*gt12				-409907	0.01574	
	1/v3.0*gt12				-6437.66742	0.02548	
	1/v3.0*gt13				735759	0.03299	
	1/v5.2*gt13				-418550104	0.03281	
Top sirloin butt (IMPS 184)	REMarb	18.082	0.6731	0.22687	0.00054045	0.00827	-1.1875
	RES_07119				-0.04495	0.0232	
	RERibEyeArea				0.0000419	0.01073	
	REPYG				0.08256	0.01421	
	v4.0*gt				-0.00006211	0.03288	
	v1.2*gt12				0.00015206	0.02962	
	v7.2*gt12				0.00033794	0.06655	
	v7.2*gt13				-0.00107	0.06571	
	v1.2*gt23				-0.00004703	0.02885	
	v1.0/gt				-123.70875	0.01936	
	v3.1/gt13				0.87908	0.01476	
	v7.0/gt13				-28.09149	0.07486	
	v7.0/gt23				280.93592	0.07912	
	1/v1.3				788252	0.09341	
	1/v5.3				-679204	0.09	
	1/v7.1				1530.63384	0.02691	
	1/v2.1*gt				-513948	0.01862	
	1/v4.2*gt				-8402929	0.05533	
	1/v5.0*gt				668847	0.01686	
	1/v2.3*gt12				11745634	0.04388	
	1/v5.0*gt12				-9358.23476	0.02917	
	1/v7.4*gt12				15640002	0.0385	
	1/v2.3*gt23				-1041462669	0.04768	
	1/v5.0*gt23				-1215442	0.01148	
	1/v6.1*gt23				1406811	0.01702	
	1/v7.3*gt23				-1292824421	0.04344	
Bottom sirloin butt (IMPS 185)	REHCW	8.083	0.6254	0.32093	-0.00414	0.06636	0.1941

	RENumberFatPieces				0.00225	0.01597	
	REQuality				-3.25516	0.10312	
	REGradientHori				-0.00052517	0.02359	
	REREA_Inch2				0.04265	0.00989	
	v4.3				-0.00014119	0.02899	
	v6.2				0.00053187	0.09896	
	v8.3				0.00021069	0.06214	
	v0.0*gt				0.00012601	0.04838	
	v7.3*gt13				-0.00001236	0.04694	
	v2.2/gt13				-0.00461	0.08609	
	1/v0.1				-464.64558	0.03094	
	1/v3.4				-238096	0.02064	
	1/v5.3				-213679	0.04518	
	1/v5.4				206758	0.01905	
	1/v8.4				172275	0.00825	
Bottom sirloin butt, flap (IMPS 185A)	REHCW	20.8796	0.4891	0.09354	-0.00077828	0.01779	0.2409
	RERibEyeArea				-0.00021106	0.04714	
	RERibEyeArea13				0.00014023	0.05281	
	RERibEyeFat12				-0.00093973	0.04389	
	RENumberFatPieces12				0.00408	0.02878	
	RENumberFatPiecesCorrected13				-0.00325	0.03294	
	RES_01991				0.00101	0.03853	
	RENumberFatPieces				0.00129	0.05548	
	REREA_Inch2				0.08639	0.01843	
	1/v2.4				-220549	0.06828	
	1/v6.0				153.17555	0.05166	
	1/v6.4*gt				164401876	0.06054	
	1/v1.1*gt12				15342	0.06708	
	1/v6.0*gt12				-10729	0.06791	
	1/v6.2*gt12				1486858	0.06475	
	1/v1.1*gt13				-3924630	0.06638	
	1/v6.0*gt23				545944	0.06849	
	1/v6.2*gt23				-125118492	0.06439	
Ball tip (IMPS 185B)	REHCW	4.9071	0.5956	0.15395	-0.00211	0.13783	-0.1336
	REGradientHori				-0.0002395	0.02371	
	REGradientVert12				0.00041239	0.02286	

	RERibEyeBroadPixel				-0.02477	0.02292	
	RERibEyeBroad_mm				0.12697	0.02295	
	v6.0*gt12				0.00468	0.17178	
	v7.2/gt12				0.00115	0.04605	
	1/v2.1				-1772.0246	0.06411	
	1/v2.3				366473	0.02443	
	1/v2.4				-535693	0.02941	
	1/v4.1				357.0491	0.06558	
	1/v8.1				-495.65603	0.15434	
	1/v6.1*gt				13065058	0.03255	
	1/v6.0*gt23				-93942	0.02232	
Tri tip (IMPS 185D)	REHCW	10.1327	0.5049	0.06472	-0.00029482	0.02575	-0.4876
	RERibEyeAreaFatCorrected13				-0.00038597	0.02573	
	RES_04729				0.00008279	0.02592	
	RENumberFatPieces				0.00022583	0.01798	
	REREA_Inch2				0.01599	0.05081	
	Konlen				0.00004335	0.01415	
	v6.2*gt				9.00E-08	0.05571	
	v8.2*gt				-5.60E-08	0.08495	
	v4.2*gt12				0.0000014	0.05256	
	v2.2*gt13				-0.0000034	0.01005	
	v8.4/gt12				0.0001909	0.10695	
	v1.2/gt13				-0.00020511	0.02931	
	1/v0.2*gt				3761022	0.03452	
	1/v0.3*gt				-9133102	0.0191	
	1/v0.0*gt12				-177.61108	0.02618	
	1/v1.2*gt12				-42318	0.02558	
	1/v4.2*gt13				22162695	0.02924	
	1/v8.2*gt13				-28567413	0.0324	
	1/v6.2*gt23				3049846	0.03658	
Tenderloin (IMPS 189A)	REMarb	14.0716	0.4135	0.10673	-0.00083117	0.04665	-0.1936
	RES_01423				0.00104	0.07561	
	RES_05875				-0.00151	0.14948	
	REREA_Inch2				-0.15016	0.04694	
	RERibEyeArea				0.00020004	0.04844	
	READJ				-0.09918	0.08088	

	1/v7.1				-37.38084	0.03942	
Flank primal, untrimmed	RERibEyeArea12	14.7218	0.4645	0.29244	-0.00015077	0.02948	-0.0035
	RERibEyeBlue23				0.00517	0.03616	
	READJ				0.16989	0.04637	
	REL_Star				0.0314	0.05698	
	REcheck1				0.67932	0.02285	
	RERibEyeBroad_mm				0.00873	0.01374	
	RERibEyeAreaFatCorrected				-0.0008165	0.0132	
	v5.1*gt				-0.00001162	0.02337	
	1/v0.3*gt				-26295523	0.04572	
	1/v6.2*gt12				283283	0.0803	
	1/v7.0*gt12				-1101.03923	0.07338	
	1/v2.2*gt13				-41568444	0.07205	
	1/v3.0*gt23				54016	0.06343	
Round, primal (IMPS 158)	REA_05514	18.9137	0.7304	0.81019	-0.00016836	0.04296	-0.0988
	REA_06045				1.13257	0.00778	
	RERibEyeHeight_mm				0.02021	0.00997	
	REQuality				9.4605	0.10444	
	RERibEyeAreaFatCorrected				0.00332	0.01682	
	v7.0*gt				-0.00324	0.01548	
	v8.0*gt				0.00328	0.0245	
	v7.0*gt13				0.29949	0.0169	
	v8.3/gt				0.09989	0.01715	
	v8.1/gt13				49.89512	0.01975	
	v8.1/gt23				-162.9959	0.00949	
	1/v4.2				83705	0.02143	
	1/v8.0				1941.72586	0.03491	
	1/v8.0*gt				-1707460	0.0386	
	1/v8.1*gt				2351905	0.0241	
	1/v7.0*gt12				-38422	0.02517	
	1/v0.3*gt13				-2.32E+10	0.01018	
	1/v0.3*gt23				7635763906	0.01033	
	1/v4.0*gt23				-388515	0.03319	
	1/v7.0*gt23				3522829	0.02724	
Knuckle (IMPS 167)	REA_06390	28.039	0.599	0.25615	-0.00014466	0.03195	-0.1467

	REA_13388				0.00039251	0.04366	
	REQuality				2.0287	0.09218	
	REHCW				0.00292	0.02082	
	v5.2				0.00387	0.03425	
	v1.2*gt				-0.00000218	0.02661	
	v3.0*gt				-0.00030736	0.09382	
	v4.0*gt				0.00162	0.04717	
	v5.3*gt				0.00000226	0.02854	
	v2.0*gt13				0.02627	0.12041	
	v6.0*gt13				-0.02687	0.13274	
	v1.3*gt23				-0.00002763	0.02949	
	v4.0*gt23				-0.01714	0.04593	
	v4.0/gt				175.80125	0.04027	
	v5.2/gt				-1.69756	0.0423	
	v1.3/gt12				0.01545	0.03001	
	v7.0/gt23				17.44671	0.07624	
	1/v8.2				18934	0.0125	
	1/v4.0*gt13				94333	0.01787	
	1/v8.2*gt13				-231462142	0.04179	
Round, inside, cap off (IMPS 169A)	REGradientHori13	22.5002	0.5836	0.27905	-0.00463	0.05575	0.3041
	REGradientHori12				0.0051	0.04868	
	RECalc_YG				-0.77178	0.129	
	READJ				1.84635	0.09617	
	REA_05514				-0.00004631	0.04568	
	RENumberFatPieces				0.00166	0.01562	
	REPYG				-0.74089	0.04901	
	v0.0				-0.24107	0.02172	
	v8.0				-0.01345	0.01841	
	v0.2/gt13				-0.00012818	0.01799	
	v3.3/gt13				-0.00082368	0.05013	
	v3.3/gt23				0.00811	0.05698	
	1/v0.1				1177.22604	0.02595	
	1/v0.0*gt12				-760.90697	0.02068	
Gooseneck, heel out (IMPS 170A)	REA_13388	23.0682	0.5991	0.37004	0.00049768	0.04928	-0.3601
	REA_14087				-0.03717	0.03766	
	RERibEyeHeight_mm				0.29091	0.01873	

	RERibEyeHeightPixel				-0.10426	0.01802	
	RERibEyeBroad_mm				0.01134	0.01518	
	REPYG				-0.13525	0.01678	
	v8.3*gt				1.06E-07	0.03783	
	v1.3*gt13				-0.0000179	0.08815	
	v2.1/gt23				-9.26836	0.05992	
	1/v0.1				135.16464	0.02411	
	1/v3.0				7.3711	0.0152	
	1/v3.3				-584254	0.05686	
	1/v5.0				184.37318	0.13194	
	1/v5.2				-119190	0.14795	
	1/v5.3				-980329	0.13747	
	1/v7.3				518863	0.05178	
	1/v8.2				102973	0.06895	
	1/v8.0*gt				-969849	0.05948	
	1/v5.4*gt12				34470999	0.13652	
	1/v5.1*gt13				-41138450	0.07129	
	1/v6.0*gt13				176905	0.03755	
	1/v5.1*gt23				15040113	0.07095	
	1/v8.0*gt23				2457892	0.05161	
Knuckle, peeled (IMPS 167A)	RENumberFatPieces23	25.809	0.6832	0.2004	-0.01024	0.03122	-0.0378
	REQuality				1.2368	0.0344	
	REGradientHori				0.00058996	0.04262	
	v3.0*gt				-0.00059761	0.07779	
	v2.0*gt13				0.017	0.06854	
	v3.2*gt13				0.000116	0.06908	
	v3.3/gt				0.8157	0.03948	
	v7.3/gt				-0.75613	0.0345	
	v7.2/gt12				-0.03619	0.07058	
	v3.0/gt13				2.31438	0.01032	
	v7.1/gt13				-2.58523	0.05807	
	1/v3.4				769169	0.04689	
	1/v6.1*gt				1028956	0.00798	
	1/v7.0*gt				7096.15034	0.01784	
	1/v3.3*gt12				-15880513	0.04229	
	1/v3.1*gt13				12599175	0.12799	

	1/v6.1*gt23				-5668922	0.02724	
	1/v8.0*gt23				-35106	0.02442	
Outside flat (IMPS 171B, PSO 3)	RENumberFatPiecesCorrected12	16.9507	0.5505	0.27772	-0.00136	0.0101	-0.0345
	REA_13388				0.00057336	0.10384	
	RES_04729				-0.00052018	0.04811	
	REcheck1				-1.09028	0.05353	
	REREA_Inch2				0.07828	0.05754	
	v1.2				0.0001101	0.03514	
	v1.4				-0.00009497	0.04863	
	v8.3*gt				4.36E-08	0.02398	
	v4.3/gt13				0.00048131	0.02762	
	1/v5.3				-349832	0.15682	
	1/v3.1*gt12				-5191.43456	0.01173	
	1/v1.3*gt13				-1.38E+10	0.06811	
	1/v1.3*gt23				4809660326	0.06647	
	1/v8.3*gt23				549763045	0.06194	
Eye of round (IMPS 171C, PSO 6)	RECalc_YG	22.4064	0.6549	0.10875	-0.45655	0.1085	-0.4491
	REPYG				-0.47824	0.0692	
	REMarb				0.00161	0.09859	
	REA_06390				-0.00015675	0.05686	
	REA_13388				0.0002517	0.05471	
	RES_10553				-0.00027192	0.03094	
	RENumberFatPieces				0.00132	0.03063	
	RERibEyeHeight_mm				0.10668	0.02317	
	RERibEyeHeightPixel				-0.04006	0.02494	
	REGradientHori				-0.00024061	0.02497	
	REcheck1				-0.33943	0.02211	
	READJ				1.20762	0.10256	
	Konlen				0.00014651	0.03065	
	v4.0*gt				-0.0000297	0.04786	
	v6.2*gt				5.82E-08	0.03121	
	v4.3/gt23				-0.0047	0.052	
	v8.3/gt23				0.00331	0.02496	
	1/v5.3				-277746	0.04575	
	1/v6.4				22495	0.02215	
	1/v5.3*gt				539451764	0.02941	

	1/v5.3*gt13				-3091848086	0.02309	
	1/v7.3*gt13				-268368749	0.02261	
	1/v8.0*gt13				-69132	0.03237	
Heel (IMPS 171F)	RERibEyeArea12	29.6179	0.7111	0.07733	0.00008198	0.01898	-0.1765
	RETotalAreaPixel				-0.00001643	0.0346	
	REGradientVert23				-0.00025572	0.02661	
	REMarb				0.00044196	0.0157	
	REA_05514				-0.00002947	0.04218	
	REA_13388				0.00005767	0.01113	
	RES_05118				1.67E-10	0.01982	
	REcheck1				-0.22847	0.02084	
	v0.4*gt				-1.63E-08	0.07043	
	v7.3*gt23				-5.93E-07	0.06046	
	v6.3/gt				-0.137	0.05897	
	v8.4/gt				0.02939	0.07454	
	v6.4/gt13				0.00135	0.05515	
	1/v0.4				-100793	0.05265	
	1/v3.1				-780.65353	0.05858	
	1/v3.1				-14577	0.04816	
	1/v5.0				667.29173	0.11383	
	1/v5.1				-161.99834	0.06451	
	1/v6.3				154644	0.0438	
	1/v2.0*gt				267055	0.03254	
	1/v4.0*gt				-25981	0.03823	
	1/v5.0*gt				494202	0.10361	
	1/v6.3*gt				-112978274	0.03556	
	1/v7.0*gt				96947	0.01331	
	1/v2.0*gt12				-4212.47218	0.03494	
	1/v3.0*gt12				754.10193	0.04203	
	1/v5.0*gt12				-36522	0.11204	
	1/v2.0*gt13				-1371752	0.02967	
	1/v6.1*gt13				-3185812	0.07461	

1/v7.0*gt13	-822360	0.01093
1/v3.1*gt23	1852659	0.05215
1/v4.2*gt23	49521246	0.03936

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[a] Dependent variables predicted as a percent of the aggregate chilled left carcass side weight.

[b] Variables in model derived from VBG 2000 factors are presented as actual name, with the prefix RE; variables in model derived from VPS 2000 factors are presented as actual name; all variables' specific measurements are undefined per technology provider's request.

[c] Lean trimmings, fat, and bone are the collective proportional-inverse byproducts of the manufactured primal and subprimal cuts.

[*] Validation R^2 = estimated adjusted R^2 (i.e., the proportion of variability in actual validation dataset yields explained by regression equations from development dataset).

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