Video Image Analysis (VIA) Determination of Percentage Subprimal Yield of Beef Carcasses

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SUMMARY

This project was conducted to test the accuracy of using the Canadian Vision System (CVS) and VIAscan™ Video Image Analysis Systems (VIA) for the prediction of subprimal yield. Carcasses (N = 290) were assigned augmented Yield Grades by the VIA systems in conjunction with USDA line graders. A panel of expert graders assigned "Gold Standard" USDA Yield Grades given unrestrained time. Carcasses were subsequently fabricated to determine subprimal yields. [1]CVS and [2]VIAscan™ augmented Yield Grades accounted for: (1) 63, 55, 30% and (2) 61, 55, and 28% of the variation in fabrication yields of closely trimmed subprimals, fat, and bone, respectively. The augmentation of USDA Yield Grades through the use of VIA technology seems to be a viable way to increase the prediction accuracy of USDA Yield Grade assignment.

Key Words: Video Image Analysis, Subprimal yield, Accuracy, Augmented Yield Grades

INTRODUCTION

Inaccuracy of USDA grade application due to time restraints, coupled with industry desire to implement a value-based marketing system, has led researchers to look for more objective grading systems that are not limited by the inconsistencies of human evaluators.

Belk et al. (1996) proposed the idea of "augmenting" application of current USDA Yield Grades using a VIA system. Augmentation would allow USDA line graders to provide input that is not currently reproducible with an instrument, while an instrument could provide information from each carcass that cannot be assessed accurately by graders, as well as make the time-sensitive computations required at commercial chain speeds (Belk et al., 1998), thus allocating more time for the grader to make a more accurate judgment of those traits for which he/she is responsible. Such a system currently is available commercially and was used in this project to predict closely trimmed subprimal yields from beef carcasses. The objective of this study was to determine the cutout prediction accuracy of a full hardware VIA system designed to augment application of USDA Yield Grades, and to compare expert and instrument-assigned marbling scores with ether extractable fat content of the *longissimus* muscle.

MATERIALS and METHODS

VIA System Description

The CVS and VIAscan™ VIA systems used in this study were composed of a portable video-imaging unit, that utilized a video assessment camera to scan and record an image of the outside surface fatness and exposed 12th/13th rib interface of beef carcass sides, as they pass by on the rail at the time of traditional grading. Images were stored in an intermediate computer system, housed in a separate standalone case coupled to the video camera unit and to the grading touch panel screen. The intermediate computer calculated the ribeye size and backfat, which was then transferred to the grading touch panel, where this data was married to the hot carcass weight and displayed as a Yield Grade for augmentation by the USDA grader.

Carcass Selection

During the course of this study, steer/heifer carcasses (N = 290) were selected on a commercial packing plant bloom chain by USDA and Colorado State University (CSU) personnel. Carcasses were selected to fill blocks of Yield Grades 1 through 5, sex class (steer and heifer), carcass-weight (light-550 to 749 pounds, heavy-750 to 1010 pounds), and side (right and left). The selected beef carcasses reflected normal mine-run production variability encountered by the packing plant over the period of time that the experiment was conducted.

Grading

Carcasses were circulated by the grading stand in a random order at normal production speeds (~340 head/hour), where one of the two real-time augmentation systems -- CVS and VIAscan™ -- were installed in connection with an augmentation touch panel used by the USDA online graders. The system was made up of a VIA camera system which fed all of the Yield Grade factors at normal production speeds to a USDA grader touch panel, where the factors were displayed to the grader for augmentation. The VIA camera unit not used during the first circulation of carcasses past the grading stand was always used during the second circulation of carcasses past the grading stand to augment Yield Grade assignment by USDA graders to each carcass. Each system recorded an image of the ribeye of the leading side of the carcass, as well as a preliminary Yield Grade (PYG). Kidney/Pelvic/ Heart (KPH) fat percentage was standardized at 2% by both of the online augmentation systems for this study or ignored as if KPH had been removed on the harvesting floor. Hot carcass weight and carcass identification were downloaded into the system from the plant's database and married to each carcass through a bar-code reader.

After each carcass passed by the grading chain and the VIA camera/bar-code reader had obtained carcass identification, weight, and ribeye area, the information was transferred to the USDA augmentation touch panel where all factors were presented to the USDA grader for adjustment, only preliminary Yield Grade and Quality Grade were assigned by the online graders. Once the grader had adjusted the preliminary Yield Grade and entered the Quality Grade, a computer system that assimilated inputs from the VIA instrument and the online graders calculated the final Yield Grade to the tenth of a grade. An expert panel of three USDA-AMS Livestock and Seed Program beef carcass evaluators were provided ample time and access to all carcasses to determine "Gold Standard" grade factors (actual and adjusted preliminary Yield Grades, percent kidney/pelvic/heart fat, hot carcass weight, ribeye area, overall maturity, and marbling score). The carcasses were then transferred across the grade chain for a second time to be analyzed by the VIA camera system which was not used the first time. Following completion of the second circulation of

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carcasses past the grading stand, selected sides were fabricated to the closely trimmed (.25 inch external fat thickness) end point to determine carcass yields.

Cutability Test

Initial chilled side weights were obtained and each primal was then weighed individually. Subprimal cuts were manufactured to a closely trimmed fat specification (.25 inch). Sequential weights (all parts remaining and removed) were retained and weighed at each stage of the fabrication process. After the proper weigh-back of 99.5% of initial chilled side weight had been reached for both the forequarter and hindquarter, a final weigh-back containing the total aggregate weight for the side was calculated. All sides used in the cutability test had final weigh-backs of at least 99.5% of the total initial chilled side weight. Cut specifications were defined according to NAMP (1997) specifications and purchaser specification options (PSO). Subprimal cuts included in this study included: chuck eye roll (NAMP 116A), clod (NAMP 114); chuck tender (NAMP 116B), lip-on ribeyeroll (NAMP 112A), striploin (NAMP 180), top sirloin butt (NAMP 184), peeled tenderloin (NAMP 189A), inside round (NAMP 168), bottom round flat (NAMP 171B), bottom round eye (NAMP 171C), and peeled knuckle (NAMP 167A).

At the time of fabrication, a sample of each ribeye (*longissimus* muscle only, dissected from all surrounding tissues and approximately 1-inch in thickness) from each side was removed from the 12th rib interface and shipped to Food Safety Net Services for determination of percent ether extractable fat content. At the laboratory, each *longissimus* muscle sample was homogenized and subjected to AOAC (1996) procedures to determine fat content.

RESULTS and DISCUSSION

Simple correlation coefficients between expert Yield Grades/Yield Grade factors and augmented Yield Grades/Yield Grade factors provided by online USDA graders and the VIA systems are shown in Table 1. CVS measured PYG (r = .66), and augmented adjusted PYG (r = .87), in addition to VIAscan™ measured PYG (r = .82), and augmented adjusted PYG (r = .87) were closely correlated with adjusted PYG measured by experts, with a significant improvement in the augmented adjusted PYG correlation, suggesting that augmentation may improve the accuracy of Yield Grade assignment to beef carcasses. Ribeye area measurement by both VIA systems was highly correlated with actual ribeye area measurements, CVS (r = .90) and VIAscan™ (r = .83), indicating that there is no need for human augmentation or ribeye area measurement. Moreover, CVS and VIAscan™ augmented Yield Grades to the tenth of a Yield Grade unit applied at chain speed was highly correlated (r =. 90 and r = .86, respectively) with final Yield Grades assigned by expert graders at leisure, with both systems accounting for 81 and 74% respectively of the observed variability in Yield Grades assigned by expert graders. These results indicated that both the CVS and VIAscan™ in conjunction with USDA line graders could assign Yield Grades nearly as accurately as an expert panel of USDA graders.

Simple correlations (Table 2) between ether extractable fat content, expert marbling score, online grader Quality Grade, VIAscan™ measured marbling percent, and CVS measured marbling percent suggested that VIAscan™ (r = .79) and CVS (r = .78) were capable of accurately predicting ether extractable fat content of the *longissimus* muscle. Additionally, both VIA systems performed better in the prediction of expert marbling scores than did Quality Grades assigned by online USDA graders (r = .68). The CVS and VIAscan™ measured marbling percent accounted for 66 and 49% of the observed variability in expert marbling score respectively, and 60 and 63% of the observed variability in ether extractable fat content respectively, while online graders Quality Grades explained 46 and 43% of the observed variability in expert marbling score and ether extractable fat content, respectively, thus indicating that VIA could be used commercially to improve the assignment of USDA Quality Grades.

Coefficient of determination (R^2) for regression models using expert and augmented Yield Grade factors with estimated, actual, standardized, and no KPH to determine the effectiveness of various augmented Yield Grades for estimating subprimal cutability yields are shown in Table 3. CVS and VIAscan™ augmented Yield Grades that excluded KPH as a Yield Grade factor explained 64 and 62% of the observed variability in subprimal yields, respectively, with an increase in the prediction accuracy. Likewise, accuracy of expert Yield Grades was not affected significantly when KPH was removed as an independent variable to predict subprimal yields, where both regression equations including and/or excluding expert KPH explained 73 and 72% of the variability in subprimal yields, respectively. This indicates that removing KPH completely from the carcass on the harvesting floor would actually increase the prediction accuracy of augmentation systems.

According to Cannell et al. (1999), Yield Grades assigned by online USDA graders explained approximately 39%, 49%, and 10% of the observed variability in subprimal yields, fat, and bone, respectively. The best regression equations for [1]CVS and [2]VIAscan™ (Table 4) developed during this study accounted for: (1) 63%, 56%, 30% and (2) 61%, 55%, and 28%, of the observed variability in subprimal yields, fat, and bone respectively with expert Yield Grade factors explaining 73%, 71%, and 47%, respectively. Augmenting the application of line graders' Yield Grade would substantially improve prediction accuracy by approximately 24 to 22%.

The augmentation of USDA line graders Yield Grade with VIA technology to the tenth of a Yield Grade unit, can significantly increase the prediction accuracy of subprimal yields in addition to USDA Quality Grades when applied in real-time.

IMPLICATIONS

The utilization of a touchpanel in conjunction with the CVS (r = .90) and VIAscan™ (r = .86) VIA systems to augment USDA Yield Grades was highly related with expert assigned Yield Grades when applied at commercial chain speeds to a tenth of a Yield Grade unit. CVS' (r = .78) and VIAscan™' (r = .79) measure of marbling percentage present in the *longissimus* muscle was moderately related with ether extractable fat content measures. Removal of KPH fat percentages from augmented Yield Grade regression equations did not affect the accuracy of cutability prediction. The best regression equations for augmented Yield Grades by [1]CVS and [2]VIAscan™ systems accounted for: (1) 63, 55, 30%, and (2) 61, 55, 28% of the variation in fabrication yields of closely trimmed subprimals, fat, and bone, resulting in accuracy levels near of those achieved by expert graders. For that reason, the augmentation of USDA Yield Grade through the use of VIA, in conjunction with USDA line graders seems to be a viable way to significantly increase the prediction accuracy of USDA Yield Grades while at the same time allowing the evolution and the long-term viability of the grading system.

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Table 1. Simple correlation coefficients between CVS Yield Grade factors, VIAscan™ Yield Grade factors and expert graders "Gold Standard" Yield Grade factors.

	Expert Grader Factors and Final Yield Grade[a]			
	MPYG	ADJPYG	REA	Final Yield Grade
CVS Factors[b]:				
CVS MPYG	.70	.66	-.18	.62
Line graders ADJPYG	.88	.87	-.20	.79
CVS REA	-.28	-.38	.90	-.62
CVS Augmented Yield Grade	.77	.79	-.50	.90
ViaScan™ Factors[c]:				
VIAscan™ MPYG	.87	.82	-.25	.76
Line graders ADJPYG	.87	.87	-.27	.80
VIAscan™ REA	-.26	-.34	.83	-.57
VIAscan™ Augmented Yield Grade	.73	.75	-.53	.86

[a]Expert factors: MPYG = measured preliminary Yield Grade, ¾ fat depth; ADJPYG = adjusted preliminary Yield Grade, REA = ribeye area,

[b]CVS factors: Fat thickness = ¾ fat depth; MPYG = measured preliminary Yield Grade, ¾ fat depth; ADJPYG = line graders adjusted preliminary Yield Grade, REA = ribeye area.

[c]VIAscan™ factors: Fat thickness = ¾ fat depth; MPYG = measured preliminary Yield Grade, ¾ fat depth; ADJPYG = line graders adjusted preliminary Yield grade, REA = ribeye area.

All correlations differed from zero ($P < .0001$).

Table 2. Simple correlation coefficients among ether extractable fat content, expert marbling score, online graders Quality Grades, VIAscan™ measured marbling percent, and CVS measured marbling percent.

	Marbling Measurements[a]			
	VIAscan™ marbling %	CVS marbling %	Expert marbling score	Online graders Quality Grade
Ether extractable fat %[b]	0.79	0.78	0.76	0.66
VIAscan™ marbling %	---	0.73	0.70	0.62
CVS marbling %	---	---	0.81	0.65
Expert marbling score	---	---	---	0.68

[a]Marbling measurements: VIAscan™ marbling % = the percent of ribeye area of marbling specs traced by the VIAscan™ camera; CVS marbling % = the percent of ribeye area of marbling specs traced by the CVS camera; Expert marbling score = Practically devoid =100, Traces =200, Slight =300, Small =400, etc; Online graders = Select, Choice, etc.

[b]Ether extractable fat content: traces = 1.74, slight = 3.00, small = 4.28, modest = 5.55, and moderate = 6.82 (Savell et al., 1986)
All correlations differed from zero (P < .0001).

Table 3. Coefficients of determination (R^2) for expert and online augmented Yield Grades for the prediction of subprimal yields.

Measures	Subprimal Yields[a] R^2
Expert Yield Grade to the tenth (Estimated KPH)[b]	.73
Expert Yield Grade to the tenth (Actual KPH)[c]	.71
Expert Yield Grade to the tenth (No KPH)[d]	.72
CVS Yield Grade to the tenth (Standardized KPH)[e]	.61
CVS Yield Grade to the tenth (Actual KPH)[c]	.63
CVS Yield Grade to the tenth (No KPH)[d]	.64
VIAscan™ Yield Grade to the tenth (Standardized KPH)[e]	.59
VIAscan™ Yield Grade to the tenth (Actual KPH)[c]	.60
VIAscan™ Yield Grade to the tenth (No KPH)[d]	.62

[a]Subprimal Yields: subprimal cuts from the round, loin, rib, and chuck trimmed to .25 inch fat depth as a percent of cold side weight.
[b]Estimated KPH: % of kidney, pelvic, and heart fat as estimated by an USDA expert panel at leisure.
[c]Actual KPH: % of cold side weight of actual kidney, pelvic, and heart fat present at the time of fabrication.
[d]No KPH: kidney, pelvic, and heart fat removed from carcass weight, cutability and Yield Grade equations.
[e]Standardized KPH: kidney, pelvic, and heart fat set at 2%.
All correlations differed from zero (P < .0001).

Table 4. Coefficient of determination (R^2) and root mean square error (RMSE) values for regression equations using Expert USDA Yield Grade factors, CVS Augmented Yield Grade Factors, and VIAscan™ Augmented Yield Grade Factors for the prediction of fabrication yields of beef carcass sides.

Fabrication Yields	R^2	RMSE	Variables in model[a]
Expert USDA Yield Grade Factors:			
Subprimal yield[b]	0.730	0.010	Expert APYG, HCW, REA, KPH
Fat yield[c]	0.705	0.016	Expert APYG, HCW, REA, KPH
Bone yield[d]	0.467	0.009	Expert APYG, HCW, REA, KPH
CVS Augmented Yield Grade Factors:			
Subprimal yield	0.628	0.011	Line grader APYG, HCW, CVS REA, STD KPH
Fat yield	0.556	0.020	Line grader APYG, HCW, CVS REA, STD KPH
Bone yield	0.295	0.011	Line grader APYG, HCW, CVS REA, STD KPH
VIAscan™ Augmented Yield Grade Factors:			
Subprimal yield	0.608	0.012	Line grader APYG, HCW, VIAscan™ REA, STD KPH
Fat yield	0.545	0.021	Line grader APYG, HCW, VIAscan™ REA, STD KPH
Bone yield	0.277	0.011	Line grader APYG, HCW, VIAscan™ REA, STD KPH

[a]Variables in model: Expert APYG = expert adjusted preliminary Yield Grade, Line Grader APYG = line grader augmented preliminary Yield Grade, HCW = hot carcass weight, REA = expert ribeye area, CVS REA = CVS measured ribeye are, VIAscan™ REA = VIAscan™ measured ribeye area, KPH = expert estimated percentage of kidney, pelvic and heart fat, and STD KPH = standardized percentage of kidney, pelvic and heart fat at 2%.
All expert USDA Yield Grade factors were applied at leisure. All CVS and VIAscan™ Augmented Yield Grade factors were applied at commercial chain speeds.
[b]Subprimal yields: subprimal cuts from the round, loin, rib, and chuck trimmed to .25-inch fat depth.
[c]Fat yield: percentage of cold side weight of fat from the production of wholesale cuts.
[d]Bone yield: percentage of cold side weight of bones removed during production of wholesale cuts.