

Evaluation of the Canadian Computer Vision System for beef carcass grading

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Background

The current beef carcass grading in United States and Canada is based on measurements on the cross section between the 12th and 13th rib. Video image analysis of this cross sectional grading site has been shown to be quite effective in predicting meat quality in terms of marbling and retail product yield (Cross et al. 1983, Newman 1984, Shackelford et al. 1998 and Wood et al. 1991). The European beef grading is primarily based on visual appraisal to classify carcasses according to conformation and fatness level. It has been implemented using video image analysis (Anonymous 1996, Sönnichsen et al. 1998 and Sørensen et al. 1998). Both the beef producers and processors recognize the merit of a fair value based grading system. Lacombe Research Centre of Agriculture & Agri-Food Canada has developed a computer vision system (CVS) for beef carcass grading which combines a system to analyze carcass conformation from a whole carcass image and another system to analyze an image of longissimus muscle cross section.

Objectives

The objectives of this study are to evaluate the online performance of the Canadian CVS for beef carcass grading in terms of its accuracy and repeatability to predict longissimus measurements and the accuracy of predicting saleable meat yield.

Methods

The Canadian CVS has two subsystems. The hot carcass imaging system captures the whole carcass images with a video camera placed at some distance away from a moving line of carcasses on the kill floor. One and two-dimensional, angular and curvature measurements are made on the image. After the carcasses chilled for 24 to 48 hours, the cold carcass imaging system captures images of the cross section between the 12 and 13th rib. The traditional measurements such as subcutaneous fat depths, longissimus area and marbling percent are made from the images of cross section. The saleable meat yield is predicted from variables of both the hot and cold carcass imaging systems.

Trials to evaluate the cold CVS were conducted in a commercial beef packing plant in five days of 1997. A total of 1024 carcasses of varying fat and marbling levels were selected. Five images were captured repeatedly within minutes on the same carcass to supply data for repeatability estimation. Repeatability is estimated as the ratio of carcass variance to the sum of carcass and within carcass variance. Acetate tracings of longissimus cross section were made on 313 carcasses to compare the CVS's and the tracing's measurements. Longissimus area and subcutaneous fat depths were measured from acetate tracings by Java Video Analysis Software and a Truevision Targa M8 frame grabber (Jandel Scientific, 2591 Kerner Blvd, San Rafael, CA 94901). USDA grade fat is the fat thickness measured at the point of $\frac{3}{4}$ of longissimus dorsi from its chine bone side, whereas the Canadian grade fat is measured as the minimum fat thickness within the fourth quarter. A total of 307 carcasses, representing a wide range of weight and fatness levels from Lacombe Research Centre and two commercial plants, were selected for the carcass tissue cutout studies. Saleable meat yield, boneless subprimals closely trimmed to $\frac{1}{4}$ " destined for boxing, was prepared from the left carcass sides according to specifications defined by Canadian Meat Council and Canadian Council of Grocery distributors. Stepwise multiple regression analysis was used to select variables with maximum coefficient of determination contribution to the models for predicting saleable meat yield from using variables from hot CVS and cold CVS alone and variables from both subsystems simultaneously. Coefficient of determination and residual standard deviation are used as measure of accuracy and precision, respectively.

Results and discussion

Repeatability estimates of subcutaneous fat depths, longissimus area and marbling percent in longissimus area from five trials are summarized in Table 1. These repeatability estimates ranged from 0.80 to 0.98. The differences between measurements obtained from acetate tracings and the averages of five CVS measurements are given in Table 2. None of these differences are statistically significant ($P > 0.05$). The biases, amounting to 3 to 8% for fat depths and 1 to 3% for longissimus area are within acceptable range. These results suggest that the Canadian CVS is highly accurate and repeatable in terms of estimating the traditional measurements on the cross section between the 12th and 13th rib.

The accuracy and precision of using measurements from Canadian CVS to predict saleable meat yield were compared to those obtained from using grader's measurements from the longissimus area (Table 3). Using either variables from hot or cold CVS alone, the accuracy and precision of predicting saleable meat yield are only marginally better than those based on grader's measurements of grade fat depth and ribeye area. However, when both the variables of hot and cold CVS are used in the prediction equation, there is a 36 to 200% increase in R^2 value, depending on the cutout study. Results of these comparisons support the contention that grading system based on conformation or information derived from a single site alone tend to limit its ability to achieve a fair value based grading system.

Conclusions

Results of this study indicate that the Canadian CVS for beef carcass grading is accurate and repeatable in terms of implementing the grading standard in Canada and US. There is a tremendous increase in accuracy and precision when both measurements from the hot and cold subsystems are used simultaneously in the prediction. Currently, there are two commercial beef plants in Canada and two in the US, representing diversified practices from a stationary grading line of 700 head per day to a moving grading line of 4000 head per day which are evaluating the Canadian CVS. Another CVS system is to be installed in New Zealand for evaluation.

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Table 1: Repeatability of longissimus area measurements

Longissimus area measurement	Study				
	S1	S2	S3	S4	S5
No of carcasses	255	221	218	195	135
No of images	965	831	1030	1075	650
Canadian grade fat (mm)	.81	.89	.90	.96	.97
USDA grade fat (mm)	.80	.89	.87	.95	.94
Longissimus area (cm ²)	.96	.95	.96	.98	.98
Marbling %	.92	.96	.94	.94	.84
Repeatability = intra carcass correlation					

Table 2: Differences between measurements from acetate tracing and averages of 5 CVS measurements

Trial	Canadian grade fat (mm)	USDA grade fat (mm)	Longissimus Area (cm ²)
S4: 195 carcasses	-.89	-.36	2.23
S5: 118 carcasses	-.78	.55	-1.25
Differences (grader's minus CVS's) are statistically not significant at P<0.01			

Table 3: Accuracy and precision of predicting saleable meat yield

Models	Study							
	C1 (n=51)		C2 (n=167)		C3 (n=40)		C4 (n=49)	
	R ²	RSD	R ²	RSD	R ²	RSD	R ²	RSD
Grader's grade fat & longissimus area	.55	1.59	.49	1.68	.23	1.83	.50	1.74
CVS hot carcass system variables	.52	1.97	.45	1.84	.46	1.97	.61	1.87
CVS cold carcass system variables	.44	1.84	.59	1.53	.37	1.72	.63	1.55
CVS hot & cold carcass system variables	.75	1.57	.70	1.38	.72	1.61	.83	1.35
R ² (coefficient of determination) measures accuracy and RSD (residual standard deviation) measures precision								