Beef Carcass Grading or Classification Using Video Image Analysis

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INTRODUCTION

Carcass value to the meat processor is determined by a number of factors, but the principal components are carcass weight, the saleable meat yield and the perceived quality of meat. The purpose of carcass grading is to provide an estimate of both meat yield and quality so that a settlement price can be determined. Therefore, it is of some importance that the procedures used to estimate meat yield and quality on the carcass are precise and repeatable. The concept of classifying or grading beef carcasses for meat yield and quality was adopted in the Canadian Beef Grading System in 1972 and has been part of USDA grading regulations for many years. Research conducted in Canada at that time determined that the yield of closely-trimmed boneless cuts had a relationship with fat thickness at the 12th rib. Fat thickness was found to explain about 40% of the variation in cut yield and was considered robust enough to place carcasses into groups with similar overall meat yield. The same concept still exists in Canadian beef grading procedures with a grade ruler (Jones et al. 1992) used to determine the carcass meat yield. The grade ruler measures fat class (fat thickness at 2 mm intervals) and muscle score (4 categories based on the size of the *longissimus thoracis*) in order to provide a prediction of carcass lean content. However, this process is time-consuming and subject to the error of human judgment.

Several other countries have been conducting research to find more accurate procedures to predict beef carcass meat yield. Denmark has developed a Beef Classification Center (BCC) which measures the dimensions (length and thickness) of the whole carcass by video image analysis, while a grader makes probe measurements of carcass fatness in order to predict carcass meat yield. The accuracy of the BCC was considered more accurate than subjective grading (in Europe, the carcasses are graded visually for fatness and muscle thickness) for assessing carcass meat yield (Sorensen et al. 1988), but each carcass required approximately 1 minute to process, making the system too slow for use in North American high-speed dressing lines. In the early 1980's, the U.S. Department of Agriculture (USDA) initiated work on video image analysis (VIA). A video camera recorded a picture of the cross-section of the rib eye and a computer estimated fat thickness and muscle area. The researchers (Cross et al. 1983) concluded that the system had great potential to predict meat yield, but the approach was later abandoned when the USDA decided, in consultation with industry input, to pursue only techniques that could be applied to unribbed warm carcasses (Cross and Whittaker 1992). Since that time, work on VIA has emerged in the UK, France and Australia. The UK work in VIA was mainly commissioned to determine objectively the composition of large amounts of ground beef. Work in France is still thought to be at the prototype stage. Australia has been developing a VIA-based grading system for beef over the last few years. The two components to the Australian system are a whole carcass assessment on the slaughter floor and a chilled carcass assessment on the cross-section of the rib eye approximately 24 hours post-slaughter.

OBJECTIVES

1. To determine the accuracy of current Canadian procedures (grade ruler) for predicting beef carcass meat yield.
2. To assess the Australian VIA grading system.

METHODS

Selection of Carcasses. Carcasses were selected on the slaughter floor of two commercial plants following final weighing and immediately prior to chilling. The carcasses were identified, chilled and held on a rail for cutting the following day. A total of 270 beef carcasses and 57 dairy carcasses were graded and cut out at one plant for a total of

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TABLE 1 – Means, Ranges and Standard Deviations (SD) for Beef and Dairy Carcass Characteristics

	Beef				Dairy			
Carcass traits	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum
Warm carcass weight kg	324.8	34.60	248.4	401.6	353.7	29.57	283.8	411.9
Grade fat mm	9.5	3.7	4.0	17.0	6.5	1.8	4.0	12.0
Average fat mm	10.4	3.5	4.0	20.0	7.2	2.1	4.0	12.7
Loin eye area (grid) cm^2	83.0	10.5	53.0	115.0	72.7	8.0	59.0	95.0
Saleable meat yield (6 mm)%	75.3	2.5	68.5	83.7	74.5	1.1	72.2	77.2
Cut yield (6 mm)%	59.1	2.0	54.6	67.3	56.4	1.1	53.2	60.0

327 carcasses and 166 beef carcasses were cut out at the other. The overall sample was 493 carcasses.

Grading and Carcass Measurements. Carcasses identified on the slaughter floor were subsequently graded the following day and placed on a separate rail. Grade fat (minimum fat thickness over the *longissimus thoracis* at the 12th rib), average fat (average of 3 measurements at the 1/4, 1/2 and 3/4 positions on the 12th rib), length and width of the rib eye muscle, rib-eye area (by grid), marbling score (AMSA standard), meat and fat color and maturity were recorded.

Cut out. All left carcass sides were cut out following a standardized procedure. Sides were cut out to a boneless standard of 6 mm fat trim. Saleable meat yield was the sum of the cut weights plus the weights of the trimmings (50, 75 and 85% lean) expressed as a percentage of side weight prior to cutting. Cut yield was the sum of the cut weights expressed as a percentage of side weight.

Australian VIA assessment. Selected carcasses were measured while moving on the rail following exit from the final carcass wash, by the whole carcass VIA system. The camera was positioned to take a lateral image of the carcass (side-on image only). Approximately 80 variables were recorded from the analysis of the image. These data would be length, width, area and depth of fat. Following the grading of these carcasses, the chilled carcass assessment system was used to record an image of the 12th rib. The image was analyzed by the system to provide a range of fat depth and area measurements along with an estimate of rib eye area.

Analysis. The collected data was analyzed in a number of ways. The chosen endpoints were ***saleable meat yield*** to 6 mm of fat trim and ***cut yield*** on the same basis. Stepwise regression was used to determine the usefulness of the whole carcass imaging system and the chilled carcass imaging system in predicting saleable and cut meat yield.

RESULTS

Variation in Overall Data. Overall means and ranges for the collected data relating to yield is shown in Table 1 for beef and dairy carcasses. For beef carcasses, warm carcass weights ranged from 248-402 kg, grade fat from 4-17 mm and rib eye area from 46.2-116.7 cm^2. Thus the original objective of sampling the current range of carcasses found in industry was realized. The yield of saleable meat trimmed to 6 mm fat ranged from 68.5-83.7%, whereas the corresponding range for cut yield was 54.6-67.3%. The difference in saleable meat yield between the highest and lowest yielding carcasses adjusted to the same weight amounted to 47.4 kg or approximately $260. Can. Dairy carcasses were heavier than beef carcasses, but had less fat cover and a lower saleable meat yield (~1.0%) and cut yield (~3.0%).

Accuracy of Current Procedures to Predict Saleable and Cut Meat Yield. Various regression relationships using grade and carcass data to predict saleable meat yield (12 mm trim) are shown in Table 2. On an overall basis, the grade ruler (ruler fat class + muscle class) had a very poor relationship with total saleable meat yield explaining 10% of the variation in this trait with an error of 2.24%. This was not improved to any great extent through the inclusion of actual rib-eye area or carcass weight. Current grading procedures were much more accurate in predicting cut yield (saleable meat yield - trim) and the grade ruler (ruler fat class + muscle score) explained 47% of the variation in this trait with an error of 1.44%. The reason for the difference in accuracy between saleable and cut yield using the grade ruler is thought to be due to the more exact nature of cut yield (closely approximates the research definition of carcass lean yield) as opposed to saleable meat yield which includes three levels of trim (50, 75 and 85% lean). The current grade ruler

TABLE 2 – Accuracy of Current Grading Procedures (Canadian) to Predict Saleable Meat Yield and Cut Yield

	Saleable Meat Yield 6 mm		Cut Yield 6 mm	
	R^2	RSD	R^2	RSD
Grade fat	0.12	2.33	0.33	1.63
Grade fat + LEA (grid)	0.13	2.32	0.48	1.44
Grade fat + LEA (grid) + HCW	0.15	2.31	0.51	1.40
Avg. fat + LEA (tracing) + HCW	0.14	2.19	0.50	1.40
Ruler fat class + muscle score	0.10	2.24	0.47	1.44
Ruler fat class + muscle score + HCW	0.11	2.23	0.49	1.43

LEA is loin eye area at 12th rib, HCW is warm carcass weight, grade fat is minimum fat at 12th rib, average fat is average of three fat measures taken at the 1/4, 1/2 and 3/4 positions over the loin eye.

TABLE 3 – Accuracy of the VIA Chiller Assessment System to Predict Saleable Meat Yield and Cut Yield

	Saleable Meat Yield 6mm			Cut Yield 6mm	
Variable	**R2**	**RSD**	**Variable**	**R2**	**RSD**
Fat depth	0.12	2.22	Fat depth	0.21	1.67
Fat depth + warm carcass weight	0.12	2.21	Fat depth + warm carcass weight	0.22	1.66
Avg. (of 5 Ausm fat depths) + Fat depth + Ausmeat EMA	0.21	2.22	Ausmeat LEA + fat depth + media fat depth + total rib - fat%	0.54	1.33
Avg. (of 5 Ausm fat depths) + Fatd + Ausmeat EMA + HCW	0.23	2.19	As above + warm carcass weight	0.55	1.32
Ausm fat depth + Ausmeat EMA + media fat depth	0.27	2.13	Ausmeat LEA + Av 5 fat depths + total rib - fat%	0.54	1.34
Ausmeat fat depth + Ausmeat EMA + media fat depth + HCW	0.28	2.12	As above + warm carcass weight	0.55	1.32

LEA is loin eye area, HCW is warm carcass weight, Ausmeat standards are Australian grade specifications

was developed to predict meat yield in the cuts rather than the saleable yield of beef from a carcass.

Accuracy of the VIA Chiller Assessment System to Predict Saleable and Cut Meat Yield. A large amount of data were collected from the video images of the cross sections of the 12th rib. Stepwise regression showed that increasing the number of fat measurements improved the accuracy of predicting saleable meat yield. However, the best relationships, shown in Table 3, indicated that about 28% of the variation of saleable meat yield was explained by image measurements from the cross section of the rib. For cut yield, as with the grade ruler, the amount of variation explained increased to about 55% with an error of about 1.32%. Thus the VIA chiller assessment system was more accurate than the grade ruler, but the overall difference between the two systems was not large. In this particular trial the grade ruler was used without any limitations of time, contrary to the case in commercial practice, so the results could be assumed to be the best possible.

Accuracy of Whole Carcass VIA Assessment System to Predict Saleable and Cut Meat Yield. The best combination of image measurements on the whole carcass had the greatest accuracy for predicting saleable meat yield. The amount of variation explained was 57% with an error of 1.65% (Table 4). This represented a considerable improvement over the VIA chiller system and the grade ruler. However, the whole carcass VIA system had an accuracy similar to that of the VIA chiller assessment system for predicting cut yield, with explained variation amounting to 42% and an error of 1.56%.

The next approach was to combine the whole carcass and chiller carcass image results and look at both systems together for their overall accuracy. Using the data from both systems gave an increase in accuracy over and above that possible from either system alone. The whole carcass and chiller VIA systems explained 69% of the variation in saleable meat yield, with an error of 1.40%, and 68% of the variation in cut yield (with an error of 1.17%). Thus, the two image assessments from the whole carcass and the cross-section of the rib together gave a major improvement in predicting the value of beef carcasses.

Accuracy of the Chiller Assessment System to Predict Marbling and Loin-Eye Area. The chiller assessments system provided two estimates of marbling fat. One was the Ausmeat marbling score (Australian marbling standard) and the other the % area that fat occupied within the loin eye. These were related to the Canadian visual marbling score. It was found that between 45% and 52% of the variation in Canadian marbling score was explained by the image data. It would seem that, while these results show promise, further work is still necessary to improve the assessment of marbling and to relate measurements to a chemical fat standard. With rib-eye area, the image explained 91% of the variation in actual rib-eye size, which is very acceptable.

CONCLUSIONS

The initial evaluation of the Australian VIA technology has shown some very promising results. Carcasses can be much more accurately appraised for their actual value than is possible using the existing manual grading procedures. Further work is presently underway in Canada on an industrial prototype of the Australian VIA beef grading system. Most of this work is directed towards technology implementation problems such as speed of operation, calibration of

TABLE 4 – Accuracy of Whole Carcass System and Combining the Whole Carcass VIA with the Chiller VIA to Predict Saleable Meat Yield and Cut Yield

	Saleable Meat Yield 6mm		Cut Yield 6mm	
	R2	**RSD**	**R2**	**RSD**
Whole carcass VIA	0.57	1.65	0.42	1.56
Whole carcass VIA + chiller VIA	0.69	1.40	0.68	1.17

the software to measure marbling and meat color and repeatability of the results. Approximately 30,000 beef carcasses have been measured with the system. The potential is not only for an accurate system to determine carcass value on individual carcasses but for a fully automated system that will have a much higher repeatability across plants. In the longer term, that should allow carcasses to be graded or classified according to an International Standard.

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GRADING SUMMARY

The results of the National Beef Instrument Assessment Plan (NBIAP) workshop held in the U.S. under the sponsorship of the National Live Stock and Meat Board were presented by Chris Calkins as an introduction to the topic. The workshop, held during the spring of 1994, identified the top applied and basic technologies for beef assessment. Applied technologies are those ready for commercial study while basic technologies are those requiring a long-term commitment to study and develop. Top applied instruments were video image analysis (VIA), ToBEC (Total Body Electrical Conductivity), Australia's Tender-Tec (tm) tenderness probe, Swatland's fluorescence probe for connective tissue, and ultrasound for seedstock producers. Basic technologies included ultrasound for tenderness, elastography, Swatland's probe, ultrasound for cutability, and development of an on-the-rail system for ToBEC. Selection criteria identified by participants of the NBIAP workshop included: (1) perform reliably under a variety of conditions, (2) easily calibrated, operated and validated, and (3) operate at commercial line speeds.

The presentation, by Steven Morgan-Jones, involved Canadian experiences with the Australian-designed VIA system. Questions and comments from the 200+ participants centered on three topics.

TECHNOLOGY OF VIA:

It was determined that VIA costs about $100,000 but the primary cost is development of software. Canada is considering plant-by-plant equations, but is eager to develop the technology. It would be expected to reduce the number of graders, but the grader would not be eliminated as someone must estimate maturity. The current slaughter-floor camera can operate in excess of 500 head per hour, but the rib-eye camera presently functions at about 250 head per hour. The rib-eye camera must work at 400 head per hour for commercial usage.

The potential problem with damage to the fat from the hide puller and trimming was recognized, and could be minimized by software. The Australian VIA system makes an estimate of fat thickness on the whole-carcass image from color gradations from fat to lean. Off-color fat was not studied, but is not expected to be a problem as most cattle are grain fed. Another potential problem is bone dust, and effects of moisture and heat ring on color and marbling estimates have not been studied. The relationship between marbling and lean color was discussed.

The inherent difficulty of predicting saleable meat yield, which includes a standard boxed meat cutout and includes lean trim from the major cuts, was acknowledged. It was suggested that total carcass dissection might be an easier endpoint to predict.

Specifics of VIA were also examined. Limitations of sequential assessment of fat thickness, rib-eye area, and then color, as conducted by the system, were compared with neural networks. Details of marbling assessment include determination of total marbling area, number and size of fat particles, and distribution. Increased resolution with the VIA is needed to obtain greater predictive accuracy.

The consensus agreement of Congress participants was that this kind of system was more likely to be used as a management tool by meat packers than as a grading system.

INTERNATIONAL STATUS

The general status of instrument grading was reviewed by participants from several countries. In the U.S., a study is being conducted which includes two VIA systems, detailed yield grade, and the ToBEC system. Canada is in the process of privatizing their grading system and anticipates no problem with the VIA system meeting established requirements for a grading instrument. There is a strong desire for the implementation of the system in Canada. Australia has developed a market-link program, similar to a strategic alliance. The VIA is used in these alliances, and another system is being used for foodservice cuts. Denmark has revised their Beef Carcass Classification System to involve only whole-carcass VIA. The system no longer requires fat probes or an enclosed light cabinet and operates at about 80 head per hour. The marketing system in Germany was briefly mentioned. It was noted that France was also developing a grading instrument, but little was known about the unit.

MEAT QUALITY

The Tender-Tec™ probe from Australia was described as a probe which measures penetration force. It is being tested in the U.S. and will soon be tested in Canada. The similarity of the concept to the Armour Tenderometer™ was noted. Swatland's probe is being manufactured as a portable prototype Connective Tissue probe and will be tested in Canada in late 1995/early 1996. The status of elastography was reviewed. Encouraging results have been noted and a prototype instrument is under construction.