FUTURE OF MEAT GRADING

# Technologies for Objective Grading/Assessment

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## Introduction

North American beef cattle have traditionally been sold for slaughter on an average price for a pen of cattle with pricing generally resulting from an assessment of the live animals. In contrast, Canadian hogs have been sold on a carcass basis since the 1960's with a payment schedule based on carcass merit. Analysis of Canadian carcass data from the results of hog grades over a 20 year period have shown a cumulative and important improvement in carcass quality (Jones, 1986). Similar changes have occurred in the U.S. with hogs over the last 10 years with processing plants mainly adopting probe-based systems for evaluating carcass quality and providing higher payments for carcasses that more closely meet the specifications for weight and lean content.

While the concept of value-based marketing for the beef industry has been discussed for a long period of time (Cross and Whittaker 1992), little progress in real terms has been made. The cornerstone to a value-based marketing system for beef is an objective system for assessing the value of individual beef carcasses. Other countries such as Denmark have led the world in developing value-based marketing systems for livestock. The Danes were the first to develop a probe-based system for assessing hog carcass lean content, which was further developed through multiple probing of the carcass (carcass classification centre) and more recently with the development of the Autofom, which provides an ultrasonic scan of the length of the carcass on the slaughter

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floor. Similarly, a system for beef classification based on video image analysis of the whole carcass (Beef Classification Centre, BCC2) has also been recently developed and is expected to be adopted by the Danish meat-processing industry.

The 1995 National Beef Quality Audit revealed that increasing red meat yield to a target carcass fatness (16.5%), a total of $47.76 could be saved per carcass marketed (National Beef Quality Audit 1995). In a period of time when beef has lost approximately 20% of its market share over the last 20 years, the cost inefficiency of producing excess fat and carcasses not meeting specifications must be addressed if beef is to have any future success in competing with the other sources of protein, such as chicken and pork.

Apart from producing a high frequency of carcasses that have excess fatness, there are no clear systems that have evolved in beef cattle to measure individual carcass value as is the case in pigs. Carcass grades for beef in both the U.S. and Canada tend to pay an average price for quite wide specifications in overall carcass fatness with severe discounts only applied to carcasses that are considered to be extremely over fat. For example, Canadian beef carcasses with 10 to 15 mm of fat are subject to an average discount of $1.44 per cwt, while those with greater fat (>15 mm) are discounted on average by $11 per cwt. Similarly in the U.S., no major discounts in carcass prices are usually apparent until carcasses fall into U.S. yield grade 4. Dolezal (1997) recently calculated that for closely-trimmed beef carcasses, U.S. yield grade 1 and 2 carcasses should receive $15 and $7 more per cwt, respectively than U.S. yield grade 3 carcasses. Few researchers have considered the range in carcass value that exists within a grade. Based on an industry cut out study (Jones et al. 1993) of 436 beef carcasses, there was about a $60 difference in saleable meat yield between the highest and lowest yielding 20% within a grade. Thus non-conformity will continue to be a major problem in the beef industry unless value-based pricing systems are introduced. Technology has now reached the stage whereby instrument grading should be available in the near future. For the purposes of this presentation, the two main factors which influence carcass value are considered to be measures of carcass meat yield and meat quality. Only those technologies which are considered to be close to market-ready will be considered.

## Accuracy and Precision

There is an unquestionable need for a carcass assessment system to be accurate (predicted value to closely represent the actual value in commercial populations), but few researchers have published information on the true accuracy of carcass assessment systems. This would involve conducting a study to develop prediction equations for saleable meat yield and then testing the developed equation on another population to determine the amount of bias. Diestre and Kempster (1985) found that a prediction equation to estimate lean yield in pigs produced significant bias when tested on separate source populations. Due to the cost of conducting extensive carcass cut-out tests, researchers have generally confined themselves to reporting the relationship of predictor variables to the end point of choice (usually some measure of carcass lean content).

Most researchers have used multiple linear regression in order to relate carcass measurements to carcass lean content or quality. It has been common to use correlations or the coefficient of determination ($R^2$) to describe the strength of the relationship between the carcass measurements and the actual value for carcass meat yield. While $R^2$ values are useful and readily understood, it should be recognized that the values are to some extent dependent on the range of data in the experiment. A simple example illustrates this principle. In a population of 165 beef carcasses (carcass weight range 259 to 402 kg) which were subject to an industry cut-out, grade factors (fat thickness, rib eye area, carcass weight) explained 96% of the variation in the weight of primal cuts trimmed to 5 mm (Jones and Robertson unpublished data). When the population was reduced to limit the weight range (310 to 350 kg, n=57), the $R^2$ value dropped to 0.80. Based on this result, different conclusions could be made depending on the range of data covered in a particular study. Thus, $R^2$ values on their own have limited value for comparisons across different studies and also within studies when different predictors are employed, and particularly if the number of observations differ for predictor variables. The residual standard deviation (RSD) is generally accepted as the statistic to define precision, but is still partly dependent on the variance of the dependent variable, and cross study comparisons based on the RSD alone will be subject to some error. The use of the $C_p$ statistic has found limited usage in carcass studies (MacNeil 1983; Gwartney et al. 1992), but probably provides the best measure of precision, since it accounts for the squared true error and the squared lack of fit. For practical purposes, all three measures ($R^2$, RSD, and $C_p$) can be used to arrive at a conclusion concerning the utility of a prediction equation, but two important points remain. For the comparison of assessment techniques, it is important to compare those techniques in the same study, if the purpose of the study is to truly compare the precision of different methodology. In studies which will develop prediction equations that are to be used in a future commercial setting, it is important for the experimental population to reflect the population that will be ultimately measured.

A large amount of confusion in relation to precision for prediction equations has also been generated by the use of weight or percentages for the dependent variable (usually carcass lean yield). $R^2$ values for predicting the weight of lean are generally considerably higher than when the same variables are used to predict the percentage or proportion of lean. However, carcass weight is often the first variable to enter a multiple regression equation, where weight of lean or saleable yield is the endpoint, and it is sometimes difficult to separate the contribution of the other predictor variables from carcass weight alone. For this reason, the preferred endpoint should be a measure of the percentage or proportional lean yield such that weight is accounted for and the true impact of the predictor variables can be assessed.

**TABLE 1. The Prediction of Beef Carcass Lean Yield (%) Using Canadian and U.S. Grading Measurements.**

| | $R^2$ | RSD |
|---|---|---|
| Canadian fat/muscle[1] | 0.43 | 1.44 |
| USDA yield grade[2] | 0.81 | 1.18 |

[1] *Commercial procedure at normal line speed*
[2] *Expert assessment to the nearest 0.1 yield grade*

**TABLE 2. Prediction of Pork Carcass Lean Yield (%) by Optical Probes.**

| | $R^2$ | RSD |
|---|---|---|
| FOM (Fat-O-Meater) | 0.90 | 2.23 |
| HGP (Hennessey Grading Probe) | 0.77 | 2.37 |

*Adapted from Fisher (1990)*

## Grading Procedures to Predict Carcass Lean Content

Grading procedures in North America make use of measurements collected at the 12th rib in beef cattle and with a fat probe in most cases for swine (for a review see Fisher 1990). Although a generalized prediction equation for beef carcasses has been developed for grading purposes in the U.S. using fat thickness, rib eye area, carcass weight and estimated kidney fat, the equation is not used in practice, since the yield grade has to be subjectively determined. Recent work by Gardner et al. (1995) has shown that when expert yield graders assigned yield grades in tenths of an yield grade with no time limit to grade a beef carcass, a relatively precise estimate of percentage boxed beef yield can be obtained (Table 1). In commercial practice when percentage carcass cut yield was estimated by the use of the grade ruler, much lower precision has been found (Jones et al. 1993). Kempster et al. (1986) reported that visual appraisal of the whole carcass side based on a 15 point scale can result in more precise predictions of yield in beef carcasses than standard carcass measurements at the 12th rib. The problem with visual assessments is the amount of time required to complete these evaluations accurately and the grader to grader variation that is usually not reported. In addition, it is unrealistic to expect single dimensional measurements at one location in a beef carcass to provide a consistent estimate of the total lean meat in the carcass. Carcasses are complex 3-dimensional objects and at best, linear measurements at one location are only likely to explain a moderate amount of the lean content variation. Current visual grading procedures will therefore not meet the requirements of a value-based marketing system, where the individual carcass has to be assessed.

In pork carcasses, because the subcutaneous fat depot is a relatively consistent depot and is a much greater proportion of total fat than in cattle or lambs (80% vs 30%), the use of single-point measurements to predict carcass lean content has been relatively successful. Probes which measure the fat thickness and lean depth of pork carcasses have been generally adopted (Table 2) and research has shown that maximum precision for predicting lean percentage is in the area between the last rib and 3rd to 4th last rib.

## Technologies to Predict Carcass Lean Content

Most of the technologies which are currently under consideration to potentially improve the assessment of predicting lean in both cattle and pigs have been known for quite some time, but have only recently reached a stage of development where they could be considered as a replacement for manual grading in beef carcasses. Some of the more novel technologies, such as computerized tomography and nuclear magnetic resonance, are not discussed since although these technologies may predict composition with great precision, they are generally considered to be unsuitable for commercial purposes (cost and speed of operations). The three technologies which have the most potential for future commercial usage in value-based marketing systems include video image analysis, ToBEC and ultrasound.

### Video Image Analysis (VIA)

Cross (1983) reported the first study on the use of VIA to predict carcass lean content in beef cattle. VIA was used to measure fat thickness and rib eye area and this early work suggested that the technology had potential for predicting carcass yield, but limited potential at the time for the prediction of quality grade. Commercial systems for assessing the composition of cuts of meat and ground meat were subsequently developed in the UK (Newman 1984, 1987). During the last 14 years, major advances have been made in the hardware features such that cameras have become much smaller, relatively inexpensive color cameras became available, the cost of computing power has radically diminished and the software has become much more user friendly. These developments have allowed VIA to be developed in several countries as a carcass grading technology (Denmark, France, Australia, Canada).

The Beef Classification Centre 1 (BCC-1) was developed in Denmark and the results for a prototype system were reported by Sorensen et al. (1988). The BCC1 was mechanically complex and used a cabinet to enclose a monochromatic camera, the lighting system and a frame to hold the carcass. In addition, a probe was used to measure fat and muscle thickness. The measurements obtained included the VIA coordinates of the carcass contour (lateral view), VIA distribution of grey tone values on the carcass surface using green illumination, probe fat depth at a rump site, and fat and muscle depth in the loin and carcass weight. Results for the BCC1 showed that it had a precision equal to visual scores of fatness and conformation for predicting saleable meat %, but it was felt that the repeatability was higher than found for human measurement (Sorensen et al. 1988). The BCC1 was never commercially adopted and work started in

**TABLE 3. Use of VIA to Predict Beef Saleable Meat Yield (%).**

| | $R^2$ | RSD |
|---|---|---|
| Canadian yield grade | 0.57 | 1.55 |
| VIA (whole carcass) | 0.67 | 1.44 |
| VIA (rib section) | 0.61 | 1.49 |
| VIA (carcass + rib) | 0.84 | 1.03 |

*Tong 1997*

1993 towards the development of the BCC2, which was installed in a commercial plant as a prototype in 1995. The BCC2 does not use a cabinet or make use of probes to measure fat thickness and muscle depth. It uses a color camera with the whole carcass measured against a green background while held in a frame. The information collected by the BCC2 takes place in three stages. The contour of the carcass is first identified, followed by an analysis of the image features. The carcass is segregated into 60 image cells and for each cell nine features are extracted. An assessment of the depth of the carcass is made by shining bands on the carcass with two projectors. Through a knowledge of the exact distance to the frame holding the carcass, the depth of the carcass at any point can be established. Further details on the BCC2 are provided by Borggaard et al. (1996) and Madsen et al. (1996). The main limitation of the BCC2 for North American usage is the current 80 carcass-per-hour limit on its operational speed, although the Danes are confident this working rate can be increased.

The Australians have also developed a beef carcass grading system based on VIA which has been trademarked as VIASCAN® and consists of two separate systems. The whole carcass VIASCAN® takes an image of the carcass moving along the rail as it exits the slaughter floor. Multiple dimensional and color measurements are recorded and used to predict meat yield. The chiller assessment VIASCAN® is a cold carcass camera system that records an image of the cross section of the loin. It can record loin eye area, fat thickness at several locations, marbling, meat color, and fat color. Jones et al. (1993) reported results for the VIASCAN® whole carcass and chiller assessment systems compared to conventional Canadian carcass grading procedures. It was found that the two VIA systems together had considerable increased precision for predicting saleable meat yield than current grading procedures. Ferguson et al. (1995) reported a study which used the VIASCAN® whole carcass system to predict saleable meat yield in five different groups of beef carcasses. The results showed precision (RSD) ranged from 1 to 1.5% compared to conventional assessment procedures (warm carcass weight and P8 fat) where the RSD ranged from 1.2 to 1.8%. It was concluded that VIA had a considerable advantage in precision over that offered by conventional carcass measurements for the prediction of saleable meat yield in groups of diverse types of carcasses. Further work on the VIASCAN® whole carcass and chiller assessment systems (Richmond et al. 1995) focused primarily on durability studies under commercial conditions and on the ability of the system to record quality information. It was found that the chiller assessment VIASCAN® was able to classify 83% of the carcasses recorded as dark cutting by an experienced grader. However, only about 57% of carcasses were correctly placed into 3 marbling categories (traces, slight, small and greater) when compared with an experienced grader's results. This would indicate that further work needs to be done on marbling assessment which is more than just a simple calculation of the area of fat contained within the loin eye muscle, and the software will need to be modified to account for the size and distribution of the marbling particles.

**TABLE 4. Use of ToBEC to Predict Lean % in Carcass, Quarters and Cuts.**

| | $R^2$ | RSD |
|---|---|---|
| Side lean | 0.75 | 1.78 |
| Hindquarter lean | 0.77 | 1.98 |
| Frontquarter lean | 0.62 | 2.68 |
| Round | 0.51 | 2.38 |
| Rib | 0.57 | 2.90 |
| Loin | 0.66 | 2.82 |
| Chuck | 0.63 | 3.20 |

*Gwartney et al. 1994*

More recently the Lacombe Research Centre has developed a grading system based on VIA (Lacombe CVS) which is a two-camera system similar to the Australian system previously described (Tong et al. 1997). The whole carcass image is saved in a compressed JPG format with a file size of 30 to 40 KB from which 450 measurements can be accessed. These include linear, angular and curvature measurements made on the lateral surface of the left carcass side. The cold-carcass camera can record rib eye area, rib eye dimensions, fat thickness at a number of locations, meat color, fat color, and marbling. Although data is presently preliminary, some very promising relationships have been found. For example, VIA explained up to 84% of the variation in percentage saleable meat yield (Table 3), and 82% of the variation in marbling. The Lacombe CVS is not limited by present slaughter and grade stand line speeds and only 1 to 2 seconds is required for both the warm and cold carcass measurements to be recorded, analysed and saved. The Lacombe CVS system is currently being beta tested at a major beef plant in Alberta and the developers expect to have commercial systems introduced for beef carcass grading by 1998.

Little or no work has examined the usefulness of VIA to predict composition in pork carcasses. A whole carcass VIA scan may provide useful information on carcass shape and when used in combination with a probe-based system can result in a beneficial increase in precision for the prediction of both carcass and lean cut yield.

### ToBEC

ToBEC or total body electrical conductivity has been modified several times since it was introduced in the 1970's

**TABLE 5. Comparison of Automated Ultrasound Measurements With Manual Measurements to Predict Carcass Lean % in Pigs.**

| | $R^2$ | RSD |
|---|---|---|
| Manual measurements | 0.71 | 1.54 |
| Automated ultrasound | 0.76 | 1.35 |

*Lui and Stouffer 1995*

**TABLE 6. Shear Force at 1 or 2 d Post-mortem and Relationship with Shear Force at 14 d Post-mortem.**

| | 1 day | 14 day | 2 day | 14 day | Accuracy% |
|---|---|---|---|---|---|
| Tender[1] | 5.2 | 4.1 | 4.7 | 3.6 | 100 |
| Intermediate | 7.4 | 5.1 | 7.0 | 4.8 | 84 |
| Tough | 10.7 | 7.3 | 9.8 | 6.8 | 70 |

*[1]Tenderness category based on shear force at 1 or 2 days post-mortem. Shackelford et al. 1997*

as a technique to evaluate the lean body mass of live pigs (originally termed the EMME or electronic meat measuring equipment). The equipment consists of a tunnel surrounded by a solenoid. The placement of a carcass in the tunnel interferes with the induced magnetic field and the energy loss is detected in the coil as an index of the conductive mass of the carcass. The conductivity of electricity through lean tissue exceeds that of fat tissue by about 20 fold and carcasses varying in composition would be expected to have a different conductivity. More details on this method are provided by Kuei et al. (1989).

Much of the work completed on ToBEC has been done with pork carcasses (Forrest et al. 1989) and providing carcass orientation is standardized and the temperature of the carcass is relatively constant, extremely high relationships have been recorded between values determined from the conductivity curve and carcass lean content and also the meat yield of the major carcass cuts. Berg et al. (1994) clearly demonstrated that ToBEC was superior to optical fat probes in predicting carcass lean content under commercial conditions. ToBEC has been used by one U.S. pork processing plant as a device to assess pork carcass lean content, but has not found widespread application to date.

ToBEC has also found commercial usage for determining the chemical lean content of boxed boneless beef in Australia. ToBEC can measure up to 1200 boxes an hour and has replaced chemical methods based on cost-effectiveness and accuracy.

Ferguson (1993) reported work which compared ToBEC and conventional carcass weight and fat depth measurements for the prediction of beef lean content. It was concluded that ToBEC provided more precise predictions of beef carcass lean content than traditional carcass measurements. Gwartney et al. (1992) determined that ToBEC could explain 85 to 90% of the variation in beef quarters and primal cuts. In further work (Gwartney et al. 1994), the precision of ToBEC was confirmed for its accuracy in predicting lean weight in carcass sides and cuts. One of the advantages of ToBEC is that it not only provides a prediction of the lean content in beef quarters but it also has utility to predict the lean content of the major primal cuts (Table 4). Major disadvantages of ToBEC are the need to take carcasses off the rail for the measurement to take place and the fact that it measures solely lean yield.

**Ultrasound**

Ultrasound has been widely used for about 40 years to predict composition in live animals, but has only been developed relatively recently for carcass assessment purposes. Miles et al. (1987, 1990) showed that the velocity of ultrasound measured in warm beef carcasses provided a more precise prediction of beef carcass lean content than visual scores for fatness and conformation. However, the technology has not been further developed as it would be difficult to scale up to meet the speed requirements of modern processing plants.

Ultrasound has been shown to be equal to or more precise than optical probes for the prediction of pork carcass lean content and is regarded as a potential replacement for probes in commercial plants. Liu and Stouffer (1995) carried out automatic calculation of fat and meat depths using an Aloka 500 with a 3.5 MHZ transducer. The results showed that 76% of the variation in meat percentage in the four major primals of pork carcasses could be determined with a RSD of 1.35% (Table 5). Work on development of a fully automated ultrasound grading system for beef (University of Illinois) found that a prototype system was less precise than current USDA grading procedures for predicting product yield, but more precise for assessing meat quality in warm, hide off carcasses. However, a major developmental project would be necessary to have such a system that would meet the needs of commercial processing plants.

The most recent development in ultrasound concerns the development of the Autofom by the Danes which consists of 16 transducers (2.0 MHZ) embedded in a U-shaped stainless steel frame. The carcass is pulled through the device and the weight of the carcass ensures contact with the transducers. Measurements are made every 5mm along the carcass length which gives about a maximum of about 3,200 measuring positions for each carcass (16 transducers x 200 measuring points), although an average of about 2000 measurements per carcass are recorded. It is possible to construct a two or three dimensional image of the carcass based on the number of measurements. More detailed discussions on the technical description of the Autofom are provided by Busk and Olsen (1996) and Brøndum and Jensen (1996). Busk and Olsen (1996) describe the current measurements that are extracted from the ultrasonic images. These include the C (thinnest fat layer on the loin), B (thickest fat measurement from C towards the ham), A (thinnest fat layer between

B and the ham) and D (thickness of loin muscle at the same position as C) measurements. The Autofom was found to be slightly less accurate than the Classification Centre for predicting both pork carcass lean and cut lean contents, but well within the limits to be used as a grading device. It has been adopted by at least one U.S. pork processor and can operate at 1200 carcasses per hour.

## Comparison of Technologies to Predict Carcass Lean Content

For the three major technologies which are considered to be the main contenders for commercial usage over the next 5 years that have been briefly reviewed (VIA, ToBEC, and ultrasound), there are features to these technologies that are attractive and those that will present barriers to commercial implementation.

### VIA

The major advantages of VIA is that it produces a video image which is a mirror of the whole carcass and the cross section of the rib eye in beef carcasses. The systems presently under development (Australia, Canada) for beef can assess both carcass lean meat content and traditional quality measurements which can be seen and verified visually. The VIA system is non-invasive and can function adequately at existing line speeds for beef. One potential disadvantage is the need to link data collected by the camera on the slaughter floor with that of the cold-carcass camera when the carcass is graded for quality assessment. This will require the design of data handling systems which function with a high degree of reliability. The VIA system still requires an operator for the cold-carcass camera and does not at present have the capability to detect maturity and no work has been done on its ability to predict cut yield. However, it is considered at present to be the most useful technology to provide a commercial grading system for beef cattle and would, if implemented, allow the introduction of a value-based marketing system. VIA does not appear to offer many advantages for the assessment of pork carcasses, but would be anticipated to have a role in the assessment of lamb carcasses.

### ToBEC

This technology is probably the most precise for predicting lean yield and cut yield in both pork and beef carcasses. However, for beef carcasses it does not have the ability to predict quality grade, which is a major disadvantage compared to VIA. It also requires carcasses to be taken off the rail for measurement, although a system to do this automatically would be feasible and would have to be re-engineered for measuring whole beef carcasses. ToBEC appears to have most value for the assessment of pork carcasses, but has not been widely adopted by the pork industry in the U.S. partly due to the cost of the equipment and the labor requirement to take carcasses off the rail.

### Ultrasound

This technology has advanced rapidly over the last few years and is seen in pigs as a replacement for the current optical probes which are widely used by the processing industry in North America. Ultrasound has the advantage of being non-invasive and the precision in predicting lean content has generally been slightly better than that recorded by optical probes. The complexity of equipment available ranges from the newer real time ultrasonic scanners (e.g. Aloka 500) to the fully automated Autofom. Decisions on adoption will largely be made on cost effectiveness, since a large plant would be required to justify the relatively high costs of the Autofom. Ultrasound is considered to be a non-viable system for the assessment of beef carcasses at its present stage of development but further work needs to be done to work on systems that can predict both yield and quality parameters.

## Technologies to Predict Carcass Quality

While there has been a large amount of work conducted to predict carcass lean content in beef and pork carcasses, there have been relatively few technologies developed that have the potential to assess potential eating quality. Marbling fat, the primary measurement made to assure eating quality in grading, only has a low relationship with taste panel tenderness.

The Australians developed a mechanical probe (Tendertec) to measure tenderness in beef but the experimental results have been disappointing. A recent study (George et al. 1997) showed that Tendertech output variables had correlations with Warner-Bratzler shear force evaluations that were not different to zero. Furthermore, Tendertec output variables had very low correlations with sensory panel assessed connective tissue and overall tenderness. In contrast, marbling score was significantly correlated with shear force and sensory panel ratings for muscle fibre tenderness, connective tissue and overall tenderness. The authors (George et al. 1997) concluded that the Tendertec did not offer much potential as a device to assess tenderness in carcasses.

Swatland (1995) discussed the development of the connective tissue (CT) probe which was demonstrated to have a moderate relationship with taste panel tenderness (R2 values with panel tenderness of 0.6 to 0.8 for semitendinosus and 0.47 to 0.65 for longissimus muscle). This probe has been subject to other tests which have shown promise in predicting tenderness, particularly when a neural network is used to describe relationships between probe readings and meat tenderness but was subject to operating failures when used in commercial conditions. The CT probe is currently being re-engineered into a commercial prototype.

Shackelford et al. (1997a) have recently pointed out that most of the technologies investigated to predict the tenderness of beef (ultrasound, elastography, near infra-red spectroscopy) have not been successful, because they do not take into account the subtle changes in raw meat that are

responsible for cooked meat tenderness. The same authors (Shackelford et al. 1997a) describe a system whereby a steak is removed from a carcass prior to grading, rapidly cooked (7 to 8 minutes) with a 10 mm thick slice (50 mm long) subject to a shear test. Steaks were classified as tender if the shear force measurement was < 6kg, intermediate if between 6 to 9 kg and tough if 9 kg or greater at 1 or 2 days postmortem. Frequency analysis showed that tenderness classification at 1 or 2 days post-slaughter gave an accurate prediction (85 to 95%) of whether the steak would have a low shear value at 14 days postmortem (Table 6). The authors have reported a second trial (Shackelford et al. 1997b) conducted under commercial conditions which confirmed that tenderness classification at 3 days postmortem could accurately place carcasses into expected palatability groups. Although this system involves the removal of a steak from the carcass, it has the most potential at present to be used as an on-line system for assessing meat tenderness in beef.

## Conclusions

Over the last five years, there have been major advances in technology and objective systems for beef carcass assessment are now feasible for introduction to the North American beef industry before the end of the century. This will provide the basis for a value-based marketing system for beef cattle as long as the necessary information and identification systems are put in place to allow the data to flow back to the primary producer. Value-based marketing has already been adopted by the pork industry and the next challenge will be whether more complex and potentially more accurate technologies will be used to replace the probe-based systems already in use. While there are some promising developments for the prediction of meat quality, the industry as a whole will have to make longer term decisions on the importance of quality to put a system in place to result in an improvement in the consistency of tenderness.

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