

INSTRUMENT ASSESSMENT OF BEEF  
CARCASS CUTABILITY USING THE  
CANADIAN COMPUTER VISION  
SYSTEM OR USDA YIELD  
GRADES

By

CLINTON EMERSON WALENCIAK

Bachelor of Science

Oklahoma State University



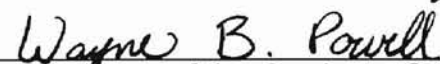
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Thesis Approved:

  
\_\_\_\_\_  
Thesis Advisor  
  
\_\_\_\_\_  
  
\_\_\_\_\_  
Dean of the Graduate College

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## CHAPTER I

### INTRODUCTION

In 1978 the USDA began looking for technologies that would perform beef grading tasks. The USDA began a cooperative effort with the National Aeronautics and Space Administration (NASA) Jet Propulsion Laboratory. NASA recommended Video Image Analysis (VIA) and Ultrasound as the two most promising technologies (Cross and Whittaker, 1992). In 1983 a VIA instrument was developed and testing began at the Meat Animal Research Center in Clay Center, Nebraska. These findings are discussed in the following literature review.

In 1994 the National Livestock and Meat Board initiated the National Beef Instrument Assessment Plan (NBIPS). The objectives of this plan were to assess the most state of the art, objective, as well as accurate, beef carcass/cut evaluation tools and to recommend an area of focus for the beef industry (NBIPS, 1994). Technologies reviewed in this symposium include video image analysis (VIA), Total Body Electrical Conductivity (ToBEC), and ultra sound.

For a technology to be acceptable it must meet the following standards; must perform reliably under a variety of conditions, be easily calibrated, operate at speeds consistent with carcass line speeds commonly found in processing plants, and must be better than current grading methods at measuring lean:fat

ratios, and estimating tenderness or palatability traits of entire carcasses and primal cuts (NBIAP, 1994). The committee chose VIA and ToBEC as the two best options.

Video Image Analysis employs the use of video cameras and computer hardware and software. The video cameras are used to create images of a whole carcass side as well as distinguishing fat, bone, and muscle at the exposed 12<sup>th</sup>/13<sup>th</sup> rib interface. Some VIA systems employ the use of a second camera system that evaluates whole carcass side characteristics. These pictures are then analyzed and objectively interpreted using computer software. After calculations are made a quality score and cutability estimate are generated.

This research was conducted with the cooperation of personnel from Oklahoma State University, Colorado State University, Excel Corporation, and the United States Department of Agriculture Marketing Service. The objectives of this project were the following:

To evaluate the ability of Canadian Computer Vision System (CCVS) to predict red meat yield as a percentage of carcass weight; and, to assess the ability of CCVS to augment USDA Yield and Quality Grades by testing objective measures of fat thickness, ribeye area, muscle color and marbling amount, as well as other quality and cutability characteristics obtained at the 12<sup>th</sup> – 13<sup>th</sup> rib interface.



## CHAPTER II

### REVIEW OF LITERATURE

#### Using Video Image Analysis to Assess Beef Carcass Traits

##### Principles of Video Image Analysis

Wood and co-workers (1991) described Video Image Analysis (VIA) as a non-invasive measure of carcass composition operating on the principle that areas of different light intensity received by the camera's photosensitive element generate different voltage so that areas of light (fat) can be quantitatively differentiated from areas of dark (i.e., lean). Fisher (1990) further described VIA as a method of creating an electronic "map" that can be interpreted based on pre-set voltage thresholds.

Most simply put, VIA is a camera integrated with a computer system. The camera provides a real-time image which is then "dissected" by the computing system. Currently there are two types of cameras available for use in VIA (Swatland, 1995). The vidicon tube camera was the first used in estimating carcass yield, followed by the charge-coupled device (CCD).

Adequate and proper lighting is a must for VIA to distinguish between fat and muscle. Cross and others (1983) reported that light must be even and diffused,

which is usually achieved with reflector plates or florescent tubes. In addition, the angle of the light source should be such that reflections are minimized.

#### Application of Video Image Analysis

Video Image Analysis is currently being used in the United States, as well as other countries such as Canada, Germany, and Australia (Gardner et al. 1995; Jones et al., 1990; Cannell et al., 1999). Video Image Analysis is used on boneless fresh and cured meats in addition to whole carcass yield estimation (Newman, 1984). In this research, Newman used VIA to predict lipid content of bacon, beef, ham, and pork samples with residual standard deviations of 1.46, 2.57, 0.93, and 1.13%, respectively.

#### Evaluation of Carcass Traits

Fat thickness. Measuring subcutaneous (s.c.) fat with VIA is challenging because of irregular fat cover associated with dressing defects. In 1983, Cross *et al.* evaluated beef carcasses by measuring subcutaneous fat at a point three quarters of the length of the longissimus muscle from the medial end. Fat thickness measurements were an average of as many as 17 individual measurements over a distance of 1.0 cm. In this study it was reported that VIA fat thickness measurements were highly correlated with actual and adjusted fat thickness ( $r=.90$  and  $.89$ , respectively). In addition, VIA fat measurements were highly correlated ( $r=.77$ ) with 9-10-11<sup>th</sup> rib lean percentage. While using the same system as Cross *et al.* (1983), Wassenberg *et al.* (1986) reported high

correlations between VIA carcass fat thickness and actual or adjusted fat thickness (.91 and .85 respectively). Cannell *et al.* (1999) reported similar results finding that VIA fat measurements taken at the three quarter mark of longissimus muscle were more highly correlated with actual fat thickness than with adjusted fat thickness ( $r=.79$  vs  $.71$ , respectively).

Fat area. Fat area is a combined measurement taken at the 12<sup>th</sup>/13<sup>th</sup> rib interface that includes both s.c. fat as well as intermuscular fat. The reasoning behind this measurement is that it might serve as an estimate for irregular external fat distribution and intermuscular (i.e., seam) fat deposition. Cross *et al.* (1983) and Wassenberg *et al.* (1986) reported simple correlations of .63 and .86 between fat area and single fat thickness and adjusted fat thickness measurements, respectively. This measurement has also shown to be highly correlated with s.c. fat thickness measurements when reported as a percentage of the total 12<sup>th</sup>/13<sup>th</sup> rib interface surface area.

Ribeye Area. Historically, accurately measuring the longissimus dorsi muscle area has posed a problem in that earlier VIA camera systems have had problems in segregating it from adjacent muscle systems (multifidus dorsi, longissimus costarum, spinalis dorsi, and intercostal muscle). Due to the inability of earlier versions of VIA to segregate different muscles at the 12<sup>th</sup>/13<sup>th</sup> rib interface, total lean area has been commonly used as an indicator of muscling. Cross *et al.* (1983) and Wassenberg *et al.* (1986) found that total lean area (cm<sup>2</sup>) was highly correlated with ribeye area ( $r=.84$  and  $.86$ , respectively). Jones *et al.*

(1990), however, found that 91% of the variation in ribeye area could be accounted for using the Chiller Assessment VIASCAN® system. Other researchers (Gardner *et al.*, 1995, and Borggaard *et al.*, 1996) have reported that actual ribeye area and VIA measurements were highly correlated ( $r=.95$  and  $.92$ , respectively). In agreeance, Cannell *et al.* (1999) found that the Australian VISCAN® ribeye measurement was highly correlated with actual ribeye area ( $r=.94$ ) and accounted for 59% of the variation in carcass yield trimmed to .64 cm of fat.

Carcass conformation. Subjectively appraising muscle while taking fatness and carcass length into account may be a useful tool in estimating lean yield of carcasses (Kempster and Harrington, 1980; Perry *et al.*, 1991). The Whole Carcass VIASCAN® currently used on Australian on the harvest floors utilizes lateral images of the lateral view of carcass sides to predict carcass yield (Ferguson *et al.*, 1995).

In the European Union, the second generation Beef Carcass Classification cente (BCC-2) is being used to assess conformation. This system uses a camera, two computers, and two slide projectors to determine three dimensional shape of beef carcasses (Boggaard *et al.*, 1996). This system was able to account for 93% of the variation in subjective conformation of carcasses (Madsen *et al.*, from Borggaard *et al.*, 1996).

Marbling Score. Cross and others (1983) and Wassengerg *et al.* (1986) attempted to objectively estimate marbling with VIA cameras. For these trials,

marbling was defined as any piece of fat (nearest .01 cm<sup>2</sup>) completely surrounded by lean. Under this definition, intermuscular fat could be included in the measurement. Marbling was expressed in three ways 1) number of fat particles 2) summation of the area of the fat particles 3) summation of the area (cm<sup>2</sup>) of the fat particles expressed as a percentage of total fat area. Cross *et al.* (1983) found a moderate correlation ( $r=.52$ ) between marbling estimated as number of fat particles and subjective marbling scores, but a low correlation ( $r=.16$ ) when expressed as a percentage of total fat area. Wassenberg *et al.* (1996) found low correlations ( $r=.19$  and  $.14$ ) between experts' marbling scores and marbling quantified by count and area, respectively.

#### Evaluation of Carcass Yields

Carcass fat. Using VIA measurements to predict separable fat (kg and percentage) from 9-10-11<sup>th</sup> rib section, Cross *et al.* (1983) found total fat area percentage accounted for 60.4% of the variation in weight and 80.8% of the variation expressed as a percentage of separable fat. When rib weight, total lean area, and fat thickness was included in prediction equations for separable fat (kg and percentage), accuracy improved with  $R^2$  values of .8611 and .8569, respectively. Wassenberg *et al.* (1986) compared the use of side weight, fat area (cm<sup>2</sup>), lean area (%/100), fat area (%/100), fat particles (number), and fat thickness (cm) to USDA Yield Grade factors in predicting kilograms and percentage of primal cut fat. Results showed that USDA factors were more

accurate in predicting both kilograms and percentage of primal fat (kilograms,  $R^2=.7588$  vs.  $.6826$ ; percentage,  $R^2=.6504$  vs.  $.5181$ , respectfully).

Lean. Numerous combinations of various VIA measurements have been used to predict saleable boxed beef yield. Morgan-Jones *et al.* (1993) tested the accuracy of the Australian VIASCAN<sup>®</sup>, in predicting carcass yield, in that measurements of fat thickness and lean area plus median fat depth and hot carcass weight were used in prediction equations. In that study, approximately one fourth of the variation in carcass yield was explained. Whole carcass VIASCAN<sup>®</sup> was found to predict carcass yield with an  $R^2$  of  $.61$ , and when Whole Carcass VIASCAN<sup>®</sup> measurements were combined with Chiller Assessment VIASCAN<sup>®</sup> variables, accuracy increased by 11%.

Ferguson *et al.* (1995) used Whole Carcass VIASCAN<sup>®</sup> to predict saleable beef yield (SBY%) in five groups of beef carcasses: (1) manufacturing cow carcasses ( $n=29$ ), accuracy in predicting SBY% was  $R^2=0.67$  and SEE 1.2, (2) Korean grass-fed carcasses ( $n=30$ ), accuracy in predicting SBY% was  $R^2=0.43$  and SEE 1.0, (3) domestic grain-fed carcasses ( $n=30$ ), accuracy in predicting SBY% was  $R^2=0.60$  and SEE 1.3, (4) Japanese grass-fed carcasses ( $n=30$ ), accuracy in predicting SBY% was  $R^2=0.69$  and SEE 1.1, and (5) Japanese grain-fed carcasses ( $n=30$ ), accuracy in predicting SBY% was  $R^2=0.39$  and SEE 1.5. Ferguson also used hot carcass weight and P8 fat depth to predict SBY%, with Whole Carcass VIASCAN<sup>®</sup> accounting for more observed variation in SBY% than

hot carcass weight and P8 fat depth for all carcass groups except Japanese grain-fed carcasses.

More recently Cannell *et al.* (1999) used Australian Dual-Component VIASCAN® alone and in conjunction with USDA Yield Grade factors to predict beef carcass yields. Chiller assessment estimated wholesale yields were more highly correlated to actual cutout yields than were hot assessments of wholesale yield (.64 vs .32, respectively). When chiller assessment ribeye area, chiller assessment median fat, hot assessment carcass length, and hot assessment carcass width were included as independent variables in regression equations, an  $R^2$  of .64 was achieved in predicting cutout yield. This value increased ( $R^2=.75$ ) when chiller assessment ribeye area was used with HCW, KPH%, and adjusted fat depth.

Shackelford *et al.* (1998) adapted a VIA system to work in conjunction with the MARC tenderness classification system. Results showed that an equation using five VIA measurements, including lean area, was the best predictor of retail product yield ( $R^2=.88$ ).

Borggaard *et al.* (1996) evaluated the second generation Beef Carcass Classification centre for the prediction of carcass yield. Findings showed an  $R^2$  of .70 for estimating percentage of carcass red meat yield.

Cross *et al.* (1983) used combinations of total lean area ( $\text{cm}^2$  and percentage) and total fat area ( $\text{cm}^2$  and %) as independent variables in multiple regression equations to predict either kilograms or percentage of lean in 9-10-11<sup>th</sup> rib sections from bullock and steer carcasses. Using total lean area as a

single variable equation accounted for 76.6% of the variation in lean weight. When total lean area was expressed as a percentage rather than an area,  $R^2$  values rose to .8160. Adding total fat area (%), rib weight (kg), and fat thickness (cm) as variables to the previous equation increased the variation accounted for to 93.6%. The maximum  $R^2$  value (.89) was achieved by using an equation with total lean area ( $\text{cm}^2$ ) and total fat area ( $\text{cm}^2$ ) as independent variables.

Wassenberg *et al.* (1986) used side weight, lean area ( $\text{cm}^2$ ), fat area (%/100), lean area (%/100), and color lightness as independent variables to predict kilograms and percentage carcass red meat yield. Carcass red meat yield was found to be more accurately predicted for kilograms than for percentage ( $R^2=.9563$  vs.  $R^2=.4636$ , respectively).

Gardner *et al.* (1995) evaluated the ability of VIA to predict beef side yields of boneless, closely-trimmed subprimals. Prediction equations were able to account for 21 to 81% of the variation in closely-trimmed subprimal weight and only 17 to 69% of the variation in subprimal yields expressed as a percentage of side weight. VIA fat thickness and ribeye area were used to predict side lean weight ( $R^2=.78$ ). These findings would suggest that VIA variables combined with rough primal weights were moderately accurate at predicting yield weights for most subprimals.

Bone. Shackelford *et al.* (1995) used carcass traits, wholesale rib dissection traits, 9-10-11<sup>th</sup> rib dissection traits, and chemical traits to predict bone yield. Findings show that wholesale rib bone yield, 9-10-11<sup>th</sup> rib bone yield, wholesale rib fat yield, 9-10-11<sup>th</sup> rib fat yield, and wholesale rib fat weight



explained 74, 64, 48, 45, and 42% of the variation in bone weight, respectively. For carcass traits, adjusted fat thickness accounted for the most variation in bone yield (35%).

### Effects of Sex-class

Initial studies (Brown and Branaman, 1934; Kemp *et al.*, 1954; Kropf and Graf, 1959) found that heifers yield more fat and a lower percentage of red meat than steers. When steer and heifer carcasses were fabricated to bone-in, closely-trimmed (1.27 or .64 cm s.c. fat thickness) retail cuts, Murphy *et al.* (1960) found no differences in yield. Kropf and Graf (1959) reported that steers had a high percentage of bone, resulting in a lower lean to bone ratio.

May *et al.* (1992) reported that estimated carcass percentage of chuck and flank were lower for heifers than for steers. In addition, heifers had higher yields for loin, rib, and brisket. The largest differences were found for the chuck roll with at least a 1% advantage for steer carcasses. May *et al.* (1992) concluded that these differences were due to seam fat deposition. Jones *et al.* (1990) was in agreement finding that carcasses from heifers produced 1.3% more chuck seam fat than steer carcasses. When evaluating carcasses from *Bos indicus* cattle, Griffen *et al.* (1992) found an increase in boneless, square-cut chuck yields (%) for steers over heifers. Knapp *et al.* (1989) compared English and exotic type steers and heifers finding similar yields for the ribeye roll.

May *et al.* (1992) reported that estimated subprimal yields (2.54 to .64 cm fat trim level) of the loin and round tended to be higher or equal for heifers than

steers. Knapp *et al.* (1989) had similar findings with increased strip loin yields (1.27 to 2.54 cm fat trim level) for heifers.

Conflicting reports include Griffin *et al.* (1992) finding that heifer carcasses produced more trimmable fat than steers. Furthermore, Murphy *et al.* (1985) found increased external fat trim (%) for heifers compared to steers with the largest differences being cod or udder fat, chuck, and rump fat trim. May *et al.* (1992), however, reported similar fat yields for steers and heifers.

### Effects of Carcass Weight

Examining the effect of carcass weight on boneless beef yield, Kropf and Graf (1959) found that boneless yield decreased and fat content increased in carcasses increasing from 363 to 408 kg. Other researchers (Murphy *et al.*, 1960; Cole *et al.*, 1962; Brungardt and Bray, 1963) concur that there is an inverse relationship between carcass weight and product yield.

When looking at light (227 to 250 kg) and heavy (318 to 340 kg) carcasses, Allen *et al.* (1968) found that light weight carcasses yielded higher percentages of retail cuts and lower percentages of fat trim than heavy carcasses; however, percentage of carcass weight as separable muscle, fat, and bone did not differ. Furthermore, Allen *et al.* (1968) reported that 12<sup>th</sup> rib fat thickness and carcass weight influence muscle and fat yields to a greater extent in light weight carcasses than heavy weights.

Kropf and Graf (1959) found that boneless beef to bone ratio was lowest in carcasses weighing from 181 to 227 kg. Contradictory, Allen *et al.* (1968) observed little effect of carcass weight on separable muscle to bone ratio.

### Effects of Gender

Knapp *et al.* (1989) compared Holstein steer and beef type steer and heifer cut yields. Results showed that, at 2.54 cm fat trim level, Holstein steers had lower major cut yields than did English steers, Exotic steers and heifers, and Bos indicus crossbred steers. When external fat was trimmed to .64 cm, the difference was not noticed. Griffin *et al.* (1992) reported that Holstein steers had lower carcass yields of boneless round, loin, and rib cuts than other sex-class/carcass type combinations. In addition, Gardner *et al.* (1995) found that when fat was trimmed to 1.9, 1.27, and .64 cm, beef type carcass yields were 12.0, 6.8, and 6.9%, respectively, higher.

Differences for primals and subprimals have been noted by Garcia-de-Siles *et al.* (1977), in that untrimmed rib yield was higher for Holstein steer carcasses than for Hereford steer carcasses. Inversely, Knapp *et al.* (1989) reported percentage rib was lower for Holstein steers than for beef type cattle trimmed to 2.54 or 1.27 cm, but percentage of rib yield was not different when fat was trimmed to .64 cm. Moreover, strip loin yields expressed as a percentage of carcass weight was lower for Holstein steers when fat was trimmed to 2.54 or 1.27 cm. At 2.54 fat rim level, Holstein steers produced carcasses with less fat trim, however, when fat was trimmed to .64 cm, Holstein and beef steers had

similar yields (Knapp *et al.*, 1989). Additionally, bone yields were higher for Holstein steers than for beef steers or heifers (19.2% vs. 16.0% or 15.0% respectively). Griffin *et al.* (1992) found that dairy steers had more bone than *Bos indicus* and beef type steers and heifers.

## LITERATURE CITED

- Allen, D.M., R.A. Merkel, W.T. Magee, and R.H. Nelson. 1968. Variation in some beef carcass compositional characteristics within and between selected weight and fat thickness ranges. *J. Anim. Sci.* 27:1239.
- Borggard, C., N.T. Madsen, and H.H. Thodberg. 1996. In-line image analysis in the harvest industry, illustrated by beef carcass classification. *Meat Science.* 43(S):S151.
- Brown, G.A., and G.A. Branaman. 1934. Retail cutting records of yearling cattle. *Proc. Am. Soc. Anim. Prod.* p.238.
- Brungart, V.H., and R.W. Bray. 1963. Estimate of retail yield of the four major cuts in the beef carcass. 22:177
- Cannell, R.C, J.D. Tatum, K.E. Belk, J.W. Wise, R.P. Clayton, and G.C. Smith. 1999. Dual-component video image analysis system (VIASCAN) as a predictor of beef carcass red meat yield percentge and for augmenting application of USDA yield grades. *J. Anim. Sci.* 77:2942.
- Cole, J.W., C.B. Ramsey, and R.H. Epley. 1962. Simplified method for predicting pounds of lean in beef carcass. 22:177.
- Cross, H.R., D.A. Gilliland, P.R. Duraland, and S. Seideman. 1983. Beef carcass evaluation by use of a video image analysis system. *J. Anim. Sci.* 57:908.
- Cross, H.R., and A.D. Whittaker. 1992. The role of instrument grading in a beef value-bases marketing system. *J. Anim. Sci.* 70:984.
- Ferguson, D.M., J.M. Thompson, D. Barrett-Lennard, and B. Sorensen. 1995. Prediction of beef carcass yield using Whole Carcass VIASCAN®. *Proceedings International Congress of Meat Science and Technology.* 41:185.
- Fisher, A.V., 1990. New approaches to measuring fat in carcasses. In *Reducing Fat in Meat Animals*, Ed. J.D. Wood and A.V. Fisher, Elsevier Applied Science, Barking, England, pp. 255-343.
- Garcia-de-Siles, J.L., J.H. Zeigler, L.L. Wilson, and J.D. Sink. 1977. Growth, Muscle and carcass characters of Hereford and Holstein steers. *J. Anim. Sci.* 44:973.

- Gardner, T.L., H.G. Dolezal, and D.M. Allen, 1995a. Utilization of video image analysis in predicting beef carcass lean product yields. Okla. Agr. Exp. Sta. Res. Rep. P943:61.
- Gardner, T.L., H.G. Dolezal, and D.M. Allen. 1995b. Utilization of video image analysis (VIA) for predicting beef subprimal yields. J. Anim. Sci. 73(suppl. 1):164 (abstr.).
- Griffin, D.B., J.W. Savell, J.B. Morgan, R.P. Garrett, and H.R. Cross. 1992. Estimates of subprimal yields from beef carcasses as affected by USDA grades, subcutaneous fat trim level, and carcass sex class and type. J. Anim. Sci. 70:2411.
- Jones, D.K., J.W. Savell, and H.R. Cross. 1990. The influence of sex-class, USDA yield grade, and USDA quality grade on seam fat trim from the primals of beef carcasses. J. Anim. Sci. 68:1987.
- Kemp, J.D., E.J. Wilford, and W.P. Garrigus. 1954. Carcass characteristics of heavy calves produced by the Kentucky cow-calf plan. J. Anim. Sci. 13(abstr.):970.
- Kempster, A.J., and G. Harrington. 1980. The value of fat corrected conformation as an indicator of beef carcass composition within and between breeds. Livest. Prod. Sci. 7:361.
- Knapp, R.H., C.A. Terry, J.W. Savell, H.R. Cross, W.L. Miles, and J.W. Edwards. 1989. Characterization of cattle types to meet specific beef targets. J. Anim. Sci. 67:2294.
- Kropf, D.H., and R.L. Graf. 1959. The effect of carcass grade, weight, and classification upon boneless beef yield. J. Anim. Sci. 18:95.
- May, S.G., W.L. Miles, J.W. Edwards, F.L. Williams, J.W. Wise, J.B. Morgan, J.W. Savell, and H.R. Cross. 1992. Beef carcass composition of harvest cattle differing in frame size, muscle score, and external fatness. J. Anim. Sci. 70:2431.
- Morgan-Jones, S.D., R.J. Richmond, and W.M. Robertson. 1995. Instrument beef grading. Meat Focus International. 4:59.
- Morgan-Jones, S.D., R.J. Richmond, W.M. Robertson, and S. Talbot. 1993. National Beef Cutout Test 1993. Mimeographed Report, pp. 1-12. Agriculture and Agri-Food Canada, Research Station, Lacombe, Alberta, Canada.

- Murphey, C.E., D.D. Johnson, G.C. Smith, H.C. Abraham, and H.R. Cross. 1985. Effects of sex-related differences in external fat deposition on subjective carcass fatness evaluations-steer versus heifer. *J. Anim. Sci.* 60:666.
- Murphey, C.E., D.K. Hallet, W.E. Tyler, and J.C. Pierce. 1960. Estimating yields of retail cuts from beef carcasses. Presented at the 62<sup>nd</sup> Meet. of the Amer. Soc. Of Anim. Prod., Livestock, Meat, Grain, and Seed Division, AMS, USDA, Washington, D.C.
- National Cattlemen's Association. 1990. Instrumental measurement of beef value recommendations from NCA sub-committee. Denver, CO.
- National Live Stock and Meat Board. 1994. The National Beef Instrument Assessment Plan. National Live Stock and Meat Board, Chicago, IL.
- Newman, P.B., 1984. The use of video image analysis for quantitative measurements of visible fat and lean in meat: part 1 – boneless fresh and cured meats. *Meat Sci.* 10:87.
- Perry, D.W, A. McKiernan, and A.P. Yeates. 1991. Meat Research Corporation Final Report: predicting meat yield from live muscle score. Meat Research Corporation, Australia.
- Shackelford, S.D., L.V. Cundiff, K.E. Gregory, and M. Koohmaraie. 1995. Predicting beef carcass cutability. *J. Anim. Sci.* 73:406.
- Shackelford, S.D., T.L. Wheeler, and M. Koohmaraie. 1998. Coupling of image analysis and tenderness classification to simultaneously evaluate carcass cutability, longissimus area, subprimal cut weights, and tenderness of beef. *J. Anim. Sci.* 76:2631
- Swatland, H.J. 1995. On-line evaluation of meat. Technomic, Lancaster, PA.
- Wassenberg, R.L., D.M. Allen, and K.E. Kemp. 1986. Video Image Analysis prediction of total kilograms and percent primal lean and fat yield of beef carcasses. *J. Anim. Sci.* 62:1609.
- Wood, J.D., P.B. Newman, C.A. Miles, and A.V. Fisher. 1991. Video Image Analysis: comparisons with other novel techniques for carcass assessment. Proceedings of Electronic Evaluation of Meat in Support of Value Based Marketing. Purdue University, West Lafayette, IN. pp. 147-174.

## PREDICTING BEEF CARCASS CUTABILITY WITH THE CANADIAN COMPUTER VISION SYSTEM OR USDA YIELD GRADES

### ABSTRACT

Beef carcasses (n=300) were selected to fill a 2x3x2 matrix of sex-class (steers or heifers), yield grade (YG1, YG2A, YG2B, YG3A, YG3B, YG4&5), and carcass weight (light = 249.5 kg – 339.7 kg; heavy = 340.2 kg – 430.5 kg). Carcasses were fabricated to boneless boxed beef product at a subcutaneous fat trim level of .64 cm. USDA Yield Grades and Canadian Computer Vision System (CCVS) were used to predict beef carcass cutability.

On-line USDA graders accounted for 42.21% of the variation in total yield while experts' application of the USDA Yield Grade equation accounted for 68.83%. CCVS predicted yield measurement accounted for 36.47% of the variation in carcass yield. The best single variable predictor of carcass yield was experts' adjusted fat thickness ( $R^2=.5902$ ). The best CCVS measurement for predicting yield was the average of the 4 fat measurements (FATAVG), ( $R^2=.4536$ ). CCVS ribeye area measurement accounted for a higher percentage of carcass yield than experts' ribeye area ( $R^2=.4202$  vs  $R^2=.3795$ , respectively).



The best prediction equation using C CVS measurements with HCW, KPH, and SEX accounted for slightly less variation in total yield than using experts' measurements plus SEX ( $R^2 = .6929$  vs.  $R^2 = .7043$ , respectively), but was still better than on-line yield grade application ( $R^2 = .4221$ ).

## INTRODUCTION

As the beef industry looks at new ways of marketing beef animals and assessing value, so to must they look at new ways of quantifying the characteristics associated with value. USDA Yield Grades do an adequate job when the appropriate factors are accurately and precisely assessed and applied to the equation. However, with chain speeds – some in excess of 400 carcasses/hr -- and pressures to perform placed on graders in today's beef processing facilities, accurate assessment of yield grade factors, and in turn carcass value, is becoming more and more difficult (Belk et al., 1996). As a result of this, many new technologies have been developed and are being tested.

Video Image Analysis was identified by the National Beef Instrumentation Plan to be one of the most promising technologies to be implemented into production settings (NBIAP, 1994).

The objective of this experiment was to evaluate the accuracy of the USDA Yield Grade equation and the Canadian Computer Vision System in predicting red meat yield and the factors associated with it under industry conditions.

## MATERIALS AND METHODS

The left or right side (left n=143; right n=164) of beef carcasses were selected on the basis of sex-class (steers and heifers), carcass weight (light = 249.5 kg – 339.7 kg; heavy = 340.2 kg – 430.5 kg), and EYG (1, 2A, 2B, 3A, 3B, 4-5) to fill a 2x6x2 matrix (Table 1). First, Carcasses were viewed on the harvest floor using the first of two phases of the Canadian Computer Vision System (CCVS). The first camera viewed the fat side of carcasses to evaluate fat coverage and distribution in addition to conformation and muscling with point to point measurements. After a 36 h chill period (0°C), carcasses were ribbed at the 12<sup>th</sup> – 13<sup>th</sup> rib interface and allowed to bloom for 10 minutes. At this time a USDA grader assigned USDA Yield Grades (USYG) to the nearest numerical grade and USDA Quality Grades (USQG) to the nearest whole grade at a chain speed of 350 to 400 carcasses per hour. Immediately after USDA grades were assigned, the second phase of the CCVS viewed carcasses at the 12<sup>th</sup> – 13<sup>th</sup> rib interface for subcutaneous fat depths at four locations (VFAT1, VFAT2, VFAT3, and VFAT4), ribeye area (VREA), percent intramuscular fat (VIM), adjusted percent intramuscular fat (VAIM), and calculating percent yield (COLD%). There are numerous other measurements taken by the hot and cold CCVS cameras. Due to patent rights, these variables will be referred to as H1, C1, H2, C2, etc.

After USDA grades were assigned and all camera images were collected, carcasses were railed off where a panel of expert graders (two USDA and two university personnel) measured preliminary fat thickness (EFAT), adjusted preliminary fat thickness (EAFAT), estimated kidney, pelvic, and heart fat

percentage (%KPH), ribeye area (EREA), skeletal maturity (SMAT), lean maturity (LMAT), overall maturity (OMAT), marbling score (MARB), and conformation score (CONF). From this data, experts calculated USDA Yield Grades (EYG), (nearest 0.01 grade), and Quality Grades (EQG), (nearest one-tenth grade). Carcasses were stationary and expert panel members were allowed to use measuring tools (e.g., ribeye grids and metal fat probes) without any time restraints.

Dressing scores (DRESS) were also assigned using a seven-point scale (7=perfectly dressed—no subcutaneous fat missing; 6=slightly less than perfectly dressed—5% of subcutaneous fat cover missing; 5=moderately less than perfectly dressed—10% of subcutaneous fat cover missing; 4=slightly more than imperfectly dressed—15% of subcutaneous fat missing; 3=moderately more than imperfectly dressed—more than 20% of subcutaneous fat missing; 2=imperfectly dressed—more than 25% subcutaneous fat missing; 1=imperfectly dressed—30% or more subcutaneous fat missing). Expert panel members also identified the primal cut location of the defects (e.g., round, loin, rib, chuck, plate, brisket, sirloin, neck) .

Once selected, carcasses were fabricated to obtain percentage yields of primal/subprimal cuts trimmed to a .64 cm fat level, lean trim, fat, and bone by an in-plant fabrication team. Fabrication followed the same procedures used by the processing plant on a daily basis with the exception of a slower chain speed. Once each primal cut passed quality assurance inspection, cuts were weighed

and recorded. Fat, bone, and lean trim were all weighed and recorded as the total generated from each carcass side.

Lean trim generated from fabrication was analyzed for percent fat content using an Infratech fat analyzer. Using the actual fat content, fat weights and lean trim weights were adjusted to more accurately reflect their contribution to overall yield.

Once all fabrication was complete and all fat and lean trim weights were adjusted, the percent recovery of each carcass was calculated using the side weights taken immediately prior to fabrication. Any carcass that deviated from 100% recovery by more than 1.0% was eliminated from the experiment leaving a total of 300 observations.

The main effects of sex-class, weight-class, and Yield Grade as well as interactions were tested using ordinary least squares procedures (SAS, 1997). Simple correlations were calculated for CCVS, USDA graders, and expert graders measurements using the CORR procedure of SAS (SAS,1997). Carcass characteristics evaluated by CCVS and expert graders, as well as USDA Yield Grades were used as independent variables in the REG procedure of SAS (SAS, 1997) to generate multiple regression equations to predict red meat yield.

## RESULTS AND DISCUSSION

All interactions among main effects were found to be non-significant ( $P>.05$ ) with the exception of percent bone yield between yield grade and sex-class. Accordingly, least squares means are reported for main effects.

Least squares means for carcass characteristics stratified by experts' Yield Grade are found in Table 2. Hot carcass weights among all Yield Grade categories were similar ( $P>.05$ ). Experts' fat thickness and experts' adjusted fat thickness increased ( $P<.01$ ), while experts' ribeye area decreased ( $P<.01$ ) as experts' Yield Grade increased. Kidney, pelvic, and heart fat percentage was highest ( $P<.05$ ) for EYG3B and EYG4&5, and lowest ( $P<.05$ ) for EYG1, EYG2A, and EYG2B. As expected, both experts' Yield Grade and USYG were all within their respective Yield Grade categories 1, 2A, 2B, 3A, 3B, and 4&5 and were different from each other ( $P<.01$ ). Conformation was found to be highest ( $P<.01$ ) for EYG 1. Marbling scores for EYG2A, EYG2B, EYG3A, EYG3B, and EYG4&5 were all in the "small" category and were more desirable ( $P<.01$ ) than EYG1.

Carcass grade characteristics stratified by sex-class are listed in Table 3. Carcass weights were higher ( $P<.01$ ) for steers than heifers. Experts' fat thickness were similar ( $P>.05$ ) among steers and heifers, however experts' adjusted fat thickness was lower ( $P<.01$ ) for steers than heifers. Kidney, pelvic, and heart fat percentage was lower ( $P<.01$ ) for steers than heifers. Experts' Yield Grade was similar ( $P>.05$ ) while USYG was lower ( $P<.01$ ) for steers than for heifers. When compared to heifer carcasses, steers had lower ( $P<.01$ ) values

for lean maturity, skeletal maturity, marbling, and USQG, as well as higher ( $P<.01$ ) values for carcass dress score (DRESS).

Table 4 displays carcass grade characteristics separated by weight-class. As would be expected, light carcasses were lighter ( $P<.01$ ) than the heavy weight-class. Light weight carcasses had less ( $P<.05$ ) measurable fat at the 12<sup>th</sup>/13<sup>th</sup> rib interface and smaller ( $P<.01$ ) ribeyes than the heavy weight-group of selected carcasses. Values for skeletal maturity were higher ( $P<.05$ ) for the heavy weight-class when compared to light-weight carcasses. Heavy weight-group carcasses also had higher ( $P<.01$ ) conformation and dress scores.

Computer Vision System measurement least squares means stratified by experts' Yield Grade are found in Table 5. Means for FAT1, FAT2, FAT3, and FATAVG increased ( $P<.01$ ) as Yield Grade increased except for EYG2B and EYG3A, while values for FAT4 were different ( $P<.01$ ) for all Yield Grade groups. Ribeye measurements decreased ( $P<.01$ ) as Yield Grade increased across all Yield Grades. Carcasses in EYG1 had the lowest values for total intramuscular fat (VIM) and adjusted intramuscular fat (VAIM) while EYG4&5 carcasses had the highest ( $P<.01$ ) values.

Instrument measurements stratified by sex-class are reported in Table 6. There were small differences ( $P>.05$ ) among steers and heifers for the four fat measurements, FATAVG, ribeye area, or intramuscular fat percentage. These findings correspond to the experts' fat measurements before adjustment. Instrument measurements stratified by weight-class (Table 7) were similar ( $P>.05$ ) except that heavy carcasses had larger ( $P<.01$ ) ribeyes than light

carcasses. These findings correspond with experts' measurements except that experts' fat thickness (EFAT) was found to be greater ( $P=.049$ ) for heavy weight carcasses

Least squares means for cutability endpoints stratified by expert's yield grade are listed in Table 8. Results show a sex-class by yield grade interaction ( $P=.013$ ) for bone percentage. Accordingly, bone is displayed by sex-class. Fat-trim percentage increased ( $P<.01$ ) as expert's yield grade increased with the exception of yield grades 2B and 3A. Lean trim percentage was highest ( $P<.01$ ) for EYG1 and EYG2A with EYG4&5 having the lowest ( $P<.01$ ) percentage of lean trim. Boxed beef (whole muscle) and total yield (whole muscle + lean trim) percentages were similar and decreased ( $P<.01$ ) as EYG numerically increased with EYG1 being the highest ( $P<.01$ ) and EYG4&5 being the lowest.

Cutability endpoints stratified by sex-class and weight-class are found in Tables 9 and 10. Percentage of bone was highest ( $P<.01$ ) for light carcasses and steers while fat trim percentage was highest ( $P<.01$ ) for heifers. Little difference ( $P>.05$ ) in percentage of lean trim among weight-classes was observed, however steer carcasses did produce higher ( $P<.01$ ) lean trim yields than heifer carcasses. There were small differences ( $P>.05$ ) between weight-class for boxed beef yield or total yield percentages. Due to lean trim yield, steers had higher ( $P<.01$ ) percentage of total yield than heifers.

Simple correlations between CCVS measurements, expert's measurements, and USDA Yield and Quality grades are found in Table 11. FAT1, FAT2, FAT3, FAT4, and FATAVG were all highly correlated with expert's



fat thickness (EFAT) at .89, .93, .92, .86, and .93, respectively. While still high, FAT1, FAT2, FAT3, FAT4, and FATAVG were less correlated to EAFAT than EFAT (.81, .84, .85, .84, .86, respectively). VREA was also highly correlated with EREA ( $r=.93$ ). This demonstrates that C CVS can accurately measure both fat thickness and ribeye area, however, C CVS lacks the ability to adjust fat thickness due to irregular fat deposition or poor hide removal. C CVS fat measurements and ribeye area measurements were more closely correlated to experts' yield grade than to USDA yield grade, and the predicted percent yield produced by C CVS was moderately correlated to expert's yield grade at  $-.70$ . Percent intramuscular fat (VIM) was better at predicting expert's marbling score than percent intramuscular fat adjusted for fat particle size (VAIM), (.75 vs. .74, respectively).

Simple correlations between C CVS measurements, yield grade, carcass traits, and cutability endpoints are presented in Tables 12 and 13. EYG was better than on-line USDA Yield Grade at predicting boxed beef yield and total yield percentages ( $-.81$  and  $-.82$  vs.  $-.61$  and  $-.64$ , respectively). FATAVG was the best camera predictor of boxed beef and total yield percentages ( $-.66$  and  $-.67$ , respectively) which was similar to EFAT. However, EAFAT was the best single measurement predictor of boxed beef and total yield percentages ( $-.73$  and  $-.76$ , respectively). Video ribeye area was found to be a better predictor of boxed beef yield and total yield than expert's ribeye area (.65 and .64 vs. .62 and .61, respectively). The C CVS predicted percent yield value was moderately



correlated to boxed beef yield and total yield percentages with simple correlations of .63 and .60, respectively.

Table 14 shows the observed variation ( $R^2$ ) in total yield percentage explained by individual VIA measurements, Yield Grade factors, and on-line or experts' yield grades. Experts' yield grade was better at estimating total yield than on-line yield grades ( $R^2=.68$  vs.  $R^2=.42$ , respectively). Experts' adjusted fat thickness (EAFAT) was the best single measurement accounting for 59.0% of the variation in total yield. The carcass yield estimate calculated by the CCVS accounted for only 36.4% of the variation in total yield. FATAVG was the best CCVS measurement predictor ( $R^2=.45$ ). Table 15 illustrates the increase in observed variation as each of the experts' measurements are added to the regression equation. Using each yield grade factor as variables in the equation rather than experts' numerical yield grade by itself accounted for 1.5% more variation in carcass yield.

Table 16 shows observed variations ( $R^2$ ) in total yield when CCVS variables are used in combination with HCW, KPH, and SEX. Recall that some of these variables are coded, however, it may be assumed that the variables H11, H43, H60, H72, H109, H118, and H120 are linear measurements taken with the hot camera and C10 and C21 are cold camera measurements taken at the 12<sup>th</sup>/13<sup>th</sup> rib interface. In this model, an  $R^2$  of .6929 can be achieved compared to using experts' yield grade factors in a model, experts' calculated numerical yield grade, or on-line USDA Yield Grades ( $R^2=.7043$ , .6883, .4221, respectively).

## IMPLICATIONS

These findings suggest that, when accurately applied, USDA Yield Grades can predict carcass yields. When CCVS fat, ribeye, and other linear measurements are implemented with hot carcass weight, kidney, pelvic, and heart fat percentage, and sex-class, accuracy is improved over current on-line USDA Yield Grade assessments. These improvements may increase further when USDA adjusted fat measurements are included, as extreme caution would be needed to account for dressing defects such as poor hide pulls and trimming.

TABLE 1. SAMPLE SIZE (N) FOUND IN EACH YIELD GRADE BY SEX-CLASS  
BY WEIGHT-CLASS CELL

	YG-1	YG-2A	YG-2B	YG-3A	YG-3B	YG-4 & 5
Light steers	9	16	14	12	12	14
Heavy steers	12	11	17	11	11	21
Light heifers	12	10	12	11	11	12
Heavy heifers	11	12	11	13	13	12

TABLE 2. CARCASS GRADE CHARACTERISTICS STRATIFIED BY EXPERTS' YIELD GRADE

Grade characteristics	Experts' Yield Grade						P
	1	2A	2B	3A	3B	4&5	
HCW, kg	341.74	344.60	335.10	339.50	338.61	345.10	.084
EFAT, cm	0.61 <sup>e</sup>	0.87 <sup>f</sup>	1.06 <sup>g</sup>	1.21 <sup>h</sup>	1.55 <sup>i</sup>	2.01 <sup>j</sup>	<.01
EAFAT, cm	0.77 <sup>e</sup>	1.06 <sup>f</sup>	1.27 <sup>g</sup>	1.46 <sup>h</sup>	1.80 <sup>i</sup>	2.19 <sup>j</sup>	<.01
EREA, cm <sup>2</sup>	100.90 <sup>e</sup>	92.58 <sup>f</sup>	86.06 <sup>g</sup>	80.65 <sup>h</sup>	78.26 <sup>h</sup>	73.74 <sup>i</sup>	<.01
KPH, %	2.31 <sup>e</sup>	2.49 <sup>ef</sup>	2.54 <sup>efg</sup>	2.44 <sup>ef</sup>	2.66 <sup>fg</sup>	2.74 <sup>g</sup>	.014
EYG	1.58 <sup>e</sup>	2.34 <sup>f</sup>	2.79 <sup>g</sup>	3.27 <sup>h</sup>	3.76 <sup>i</sup>	4.43 <sup>j</sup>	<.01
USYG	1.21 <sup>e</sup>	1.83 <sup>f</sup>	2.17 <sup>g</sup>	2.47 <sup>h</sup>	2.91 <sup>i</sup>	3.41 <sup>j</sup>	<.01
SMAT <sup>a</sup>	173.04	168.72	172.78	172.52	171.23	172.26	.80
LMAT <sup>a</sup>	153.16	149.93	155.63	152.88	149.87	153.04	.47
CONF <sup>b</sup>	509.31 <sup>e</sup>	492.80 <sup>f</sup>	480.28 <sup>g</sup>	476.97 <sup>gh</sup>	470.61 <sup>gh</sup>	467.02 <sup>h</sup>	<.01
MARB <sup>c</sup>	379.79 <sup>e</sup>	423.50 <sup>f</sup>	432.66 <sup>f</sup>	453.10 <sup>fg</sup>	448.10 <sup>f</sup>	484.85 <sup>g</sup>	<.01
USQG <sup>d</sup>	3.29 <sup>e</sup>	3.63 <sup>f</sup>	3.74 <sup>fg</sup>	3.68 <sup>f</sup>	3.75 <sup>fh</sup>	3.90 <sup>gh</sup>	<.01
DRESS	6.27	6.16	6.17	6.12	6.08	6.02	.38

<sup>a</sup> SMAT(skeletal maturity) and LMAT (lean maturity): 100 – 199 = A maturity;  
200 – 299 = B maturity

<sup>b</sup> CONF (conformation): 300-399=Select; 400-499=Choice; 500-599=Prime

<sup>c</sup> MARB (marbling): 300-399=slight; 400-499=small

<sup>d</sup> USQG (on-line quality grade): 3=Select; 4=Choice

<sup>efghij</sup> means in the same row with a common superscript were not different  
(P>.05)

TABLE 3. CARCASS GRADE CHARACTERISTICS STRATIFIED BY SEX-CLASS

Grade characteristics	Sex-class		
	Steer	Heifer	P
HCW, kg	351.50	330.03	<.01
EFAT, cm	1.18	1.25	.130
EAFAT, cm	1.33	1.52	<.01
EREA, cm <sup>2</sup>	84.71	86.00	.104
KPH, %	2.33	2.73	<.01
EYG	3.01	3.04	.425
USYG	2.23	2.44	<.01
SMAT <sup>a</sup>	165.76	177.76	<.01
LMAT <sup>a</sup>	149.27	155.56	<.01
CONF <sup>b</sup>	480.02	485.64	.099
MARB <sup>c</sup>	420.23	453.76	<.01
USQG <sup>d</sup>	3.57	3.76	<.01
DRESS	6.30	5.99	<.01

<sup>a</sup> SMAT(skeletal maturity) and LMAT (lean maturity): 100 – 199 = A maturity; 200 – 299 = B maturity

<sup>b</sup> CONF (conformation): 300-399=Select; 400-499=Choice; 500-599=Prime

<sup>c</sup> MARB (marbling): 300-399=slight; 400-499=small

<sup>d</sup> USQG (on-line quality grade): 3=Select; 4=Choice

TABLE 4. CARCASS GRADE CHARACTERISTICS STRATIFIED BY WEIGHT-CLASS

Grade Characteristics	Weight-class		
	Light	Heavy	P
HCW, kg	315.40	366.14	<.01
EFAT, cm	1.17	1.26	.049
EAFAT, cm	1.42	1.43	.620
EREA, cm <sup>2</sup>	80.39	90.32	<.01
KPH, %	2.52	2.54	.702
EYG	3.05	3.01	.165
USYG	2.34	2.33	.863
SMAT <sup>a</sup>	169.73	173.79	.035
LMAT <sup>a</sup>	152.74	152.09	.731
CONF <sup>b</sup>	475.74	489.93	<.01
MARB <sup>c</sup>	434.92	439.10	.672
USQG <sup>d</sup>	3.66	3.67	.810
DRESS	6.05	6.23	<.01

<sup>a</sup> SMAT(skeletal maturity) and LMAT (lean maturity): 100 – 199 = A maturity; 200 – 299 = B maturity

<sup>b</sup> CONF (conformation): 300-399=Select; 400-499=Choice; 500-599=Prime

<sup>c</sup> MARB (marbling): 300-399=slight; 400-499=small

<sup>d</sup> USQG (on-line quality grade): 3=Select; 4=Choice

TABLE 5. VIA CAMERA MEASUREMENTS STRATIFIED BY EXPERTS' YIELD GRADE

VIA measurements	Experts' Yield Grade						P
	1	2A	2B	3A	3B	4&5	
VFAT1, cm	0.78 <sup>d</sup>	1.02 <sup>e</sup>	1.28 <sup>f</sup>	1.43 <sup>f</sup>	1.79 <sup>g</sup>	2.19 <sup>h</sup>	<.01
VFAT2, cm	0.72 <sup>d</sup>	0.95 <sup>e</sup>	1.18 <sup>f</sup>	1.29 <sup>f</sup>	1.65 <sup>g</sup>	2.11 <sup>h</sup>	<.01
VFAT3, cm	0.75 <sup>d</sup>	0.93 <sup>e</sup>	1.17 <sup>f</sup>	1.30 <sup>f</sup>	1.62 <sup>g</sup>	2.04 <sup>h</sup>	<.01
VFAT4, cm	0.60 <sup>d</sup>	0.82 <sup>e</sup>	0.96 <sup>f</sup>	1.13 <sup>g</sup>	1.47 <sup>h</sup>	1.84 <sup>i</sup>	<.01
FATAVG, cm <sup>2a</sup>	0.71 <sup>d</sup>	0.93 <sup>e</sup>	1.15 <sup>f</sup>	1.29 <sup>f</sup>	1.63 <sup>g</sup>	2.05 <sup>h</sup>	<.01
VREA, cm <sup>2</sup>	109.10 <sup>d</sup>	98.72 <sup>e</sup>	91.99 <sup>f</sup>	86.80 <sup>g</sup>	81.06 <sup>h</sup>	77.04 <sup>i</sup>	<.01
VIM, % <sup>b</sup>	2.74 <sup>d</sup>	3.61 <sup>e</sup>	4.07 <sup>e</sup>	4.15 <sup>e</sup>	3.71 <sup>e</sup>	4.87 <sup>f</sup>	<.01
VAIM, % <sup>c</sup>	2.06 <sup>d</sup>	2.67 <sup>e</sup>	3.01 <sup>e</sup>	2.99 <sup>e</sup>	2.75 <sup>e</sup>	3.41 <sup>f</sup>	<.01

<sup>a</sup> FATAVG = FAT1+FAT2+FAT3+FAT4 / 4

<sup>b</sup> Video intramuscular fat (VIM): intramuscular fat expressed as a percentage of ribeye area

<sup>c</sup> Video adjusted intramuscular fat (VAIM): intramuscular fat adjusted for particle size and expressed as a percentage of ribeye area

<sup>defghi</sup> means in the same row with a common superscript are not different (P>.05)

TABLE 6. VIA CAMERA MEASUREMENTS STRATIFIED BY SEX-CLASS

VIA measurements	SEX-CLASS		
	STEER	HEIFER	P
VFAT1, cm	1.39	1.43	.409
VFAT2, cm	1.28	1.35	.173
VFAT3, cm	1.27	1.34	.091
VFAT4, cm	1.11	1.17	.087
FATAVG, cm <sup>a</sup>	1.26	1.32	.133
VREA, cm <sup>2</sup>	91.20	90.37	.387
VIM, % <sup>b</sup>	3.83	3.88	.774
VAIM, % <sup>c</sup>	2.80	2.83	.767

<sup>a</sup> FATAVG = FAT1+FAT2+FAT3+FAT4 / 4

<sup>b</sup> Video intramuscular fat (VIM): intramuscular fat expressed as a percentage of ribeye area

<sup>c</sup> Video adjusted intramuscular fat (VAIM): intramuscular fat adjusted for particle size and expressed as a percentage of ribeye area



TABLE 7. VIA CAMERA MEASUREMENTS STRATIFIED BY WEIGHT-CLASS

VIA measurements	Weight-class		
	Light	Heavy	P
VFAT1, cm	1.38	1.45	.159
VFAT2, cm	1.28	1.36	.084
VFAT3, cm	1.29	1.32	.380
VFAT4, cm	1.12	1.16	.269
FATAVG, cm <sup>a</sup>	1.26	1.32	.153
VREA, cm <sup>2</sup>	85.92	95.65	<.01
VIM, % <sup>b</sup>	3.78	3.94	.336
VAIM, % <sup>c</sup>	2.76	2.87	.331

<sup>a</sup> FATAVG = FAT1+FAT2+FAT3+FAT4 / 4

<sup>b</sup> Video intramuscular fat (VIM): intramuscular fat expressed as a percentage of ribeye area

<sup>c</sup> Video adjusted intramuscular fat (VAIM): intramuscular fat adjusted for particle size and expressed as a percentage of ribeye area

TABLE 8. CARCASS CUTABILITY ENDPOINTS STRATIFIED BY EXPERTS YIELD GRADE

Cutability endpoints <sup>a</sup>	Expert's Yield Grade						P
	1	2A	2B	3A	3B	4&5	
Bone, %							
Steer	16.18	15.59	15.99	15.87	14.90	14.77	.013 <sup>b</sup>
Heifers	14.60	14.59	14.48	14.26	14.47	14.01	
Fat, %	13.07 <sup>d</sup>	14.92 <sup>e</sup>	16.51 <sup>f</sup>	17.08 <sup>f</sup>	18.69 <sup>g</sup>	20.84 <sup>h</sup>	<.01
Lean trim, %	16.77 <sup>d</sup>	16.63 <sup>de</sup>	16.42 <sup>ef</sup>	16.18 <sup>fg</sup>	16.01 <sup>g</sup>	15.42 <sup>h</sup>	<.01
Boxed beef, %	54.69 <sup>d</sup>	53.15 <sup>e</sup>	51.66 <sup>f</sup>	51.50 <sup>f</sup>	50.40 <sup>g</sup>	49.04 <sup>h</sup>	<.01
Total yield <sup>c</sup> , %	71.47 <sup>d</sup>	69.78 <sup>e</sup>	68.08 <sup>f</sup>	67.69 <sup>f</sup>	66.41 <sup>g</sup>	64.46 <sup>h</sup>	<.01

<sup>a</sup> Expressed as a percentage of aggregate side weight

<sup>b</sup> Probability of experts' yield grade by sex-class interaction

<sup>c</sup> Total yield=(boxed beef+lean trim)

<sup>defgh</sup> means in the same row with a common superscript are not different (P>.05)

TABLE 9. CARCASS CUTABILITY ENDPOINTS STRATIFIED BY SEX-CLASS

Cutability endpoint <sup>a</sup>	Sex-class		
	Steer	Heifer	P
Fat, %	16.01	17.70	<.01
Lean trim, %	16.50	15.97	<.01
Boxed beef, %	51.76	51.73	0.86
Total yield, % <sup>b</sup>	68.26	67.70	<.01

<sup>a</sup> Expressed as a percentage of aggregate side weight

<sup>b</sup> Total yield=(boxed beef+lean trim)

TABLE 10. CARCASS CUTABILITY ENDPOINTS STRATIFIED BY WEIGHT-CLASS

Cutability endpoint <sup>a</sup>	Weight-class		P
	Light	Heavy	
Bone, %	15.15	14.80	<.01
Fat, %	16.82	16.88	0.79
Lean trim, %	16.19	16.28	0.34
Boxed beef, %	51.65	51.83	0.28
Total yield, % <sup>b</sup>	67.84	68.12	0.16

<sup>a</sup> Expressed as a percentage of aggregate side weight

<sup>b</sup> Total yield=(boxed beef+lean trim)

TABLE 11. SIMPLE CORRELATION COEFFICIENTS BETWEEN EXPERT MEASUREMENTS AND VIA CAMERA MEASUREMENTS

	n	EFAT	EAFAT	EREA	KPH%	MARB	CONF	EYG	USYG	USQG
VFAT1	296	.89**	.81**	-.45**	.10	.22**	-.24**	.76**	.69**	.24**
VFAT2	296	.93**	.84**	-.44**	.09	.25**	-.25**	.77**	.73**	.25**
VFAT3	296	.92**	.85**	-.47**	.10	.27**	-.26**	.79**	.71**	.27**
VFAT4	296	.86**	.84**	-.48**	.10	.25**	-.25**	.79**	.70**	.25**
FATAVG <sup>b</sup>	296	.93**	.86**	-.48**	.10	.26**	-.26**	.80**	.73**	.26**
VREA	296	-.48**	-.56**	.93**	-.05	-.29**	.57**	-.77**	-.59**	-.30**
COLD% <sup>c</sup>	296	-.70**	-.69**	.52**	.00	-.35**	.34**	-.70**	-.60**	-.31**
HOT% <sup>c</sup>	296	-.15*	-.18*	.11	.03	-.32**	.04	-.17*	-.17*	-.20*
VIM <sup>d</sup>	296	.35**	.37**	-.22**	-.03	.75**	-.26**	.37**	.31**	.60**
VAIM <sup>e</sup>	296	.33**	.34**	-.25**	-.01	.74**	-.28**	.36**	.31**	.61**

<sup>a</sup> \*P<.01, \*\*P<.001

<sup>b</sup> FATAVG=FAT1+FAT2+FAT3+FAT4/4

<sup>c</sup> Video image analysis cold and hot camera predicted percent yield

<sup>d</sup> Video intramuscular fat (VIM): intramuscular fat expressed as a percentage of ribeye area

<sup>e</sup> Video adjusted intramuscular fat (VAIM): intramuscular fat adjusted for particle size and expressed as a percentage of ribeye area

TABLE 12. SIMPLE CORRELATION COEFFICIENTS BETWEEN VIA CAMERA MEASUREMENTS AND CARCASS CUTABILITY ENDPOINTS<sup>d</sup>

	n	Bone, %	Fat, %	Lean trim, %	Boxed beef, %	Total yield <sup>e</sup> , %
VFAT1	296	-.31**	.67**	-.36**	-.63**	-.64**
VFAT2	296	-.33**	.68**	-.36**	-.64**	-.65**
VFAT3	296	-.33**	.69**	-.37**	-.64**	-.66**
VFAT4	296	-.31**	.67**	-.32**	-.64**	-.64**
FATAVG <sup>b</sup>	296	-.33**	.70**	-.37**	-.66**	-.67**
VREA	296	.002	-.55**	-.31**	.65**	.64**
COLD % <sup>c</sup>	296	.19**	-.59**	.23**	.63**	.60**
HOT % <sup>c</sup>	296	.18*	-.19**	.10	.13	.15*

<sup>a</sup> \*P<.01, \*\*P<.001

<sup>b</sup> FATAVG=FAT1+FAT2+FAT3+FAT4/4

<sup>c</sup> Video image analysis cold and hot camera predicted percent yield

<sup>d</sup> Carcass cutability end points expressed as a percentage of aggregate side weight

<sup>e</sup> Total yield%=(boxed beef+lean trim)

TABLE 13 SIMPLE CORRELATION COEFFICIENTS BETWEEN CARCASS TRAITS, YIELD GRADE, AND CARCASS CUTABILITY ENDPOINTS<sup>a</sup>

	n	Bone, %	Fat, %	Lean trim, %	Boxed beef, %	Total yield, % <sup>c</sup>
USYG	300	-.32**	.67**	-.40**	-.61**	-.64**
EYG	300	-.26**	.81**	-.47**	-.81**	-.82**
EFAT	300	-.35**	.70**	-.38**	-.65**	-.66
EAFAT	300	-.46**	.83**	-.47**	-.73**	-.76**
EREA	300	-.08	-.49**	.27**	.62**	.61**
KPH	300	-.36**	.36**	-.44**	-.13	-.26**
HCW	300	-.04	-.001	.07	-.008	.01

<sup>a</sup> Carcass cutability end points expressed as a percentage of aggregate side weight

<sup>b</sup> \*P<.01, \*\*P<.001

<sup>c</sup> Total yield=(boxed beef+lean trim)

TABLE 14. OBSERVED VARIATION ( $R^2$ ) IN TOTAL YIELD (% SIDE WEIGHT BASIS) EXPLAINED BY AN INDIVIDUAL INDEPENDENT VARIABLE

Independent variable	Code	$R^2$	RSD (%)
Experts' yield grade	EYG	.6883	1.58
USDA yield Grade	USYG	.4221	2.16
Experts' fat thickness, cm	EFAT	.4473	2.11
Experts' adjusted fat thickness, cm	EAFAT	.5902	1.82
Camera, FAT1, cm	VFAT1	.4138	2.17
Camera, FAT2, cm	VFAT2	.4303	2.14
Camera, FAT3, cm	VFAT3	.4382	2.13
Camera, FAT4, cm	VFAT4	.4125	2.17
Camera, FATAVG, cm	FATAVG	.4536	2.10
Experts' ribeye area, cm <sup>2</sup>	EREA	.3795	2.23
Camera, ribeye area, cm <sup>2</sup>	VREA	.4202	2.16
Experts' kidney/heart/pelvic fat, %	KPH	.0739	2.73
Camera, cold predicted yield, %	COLD%	.3647	2.26
Camera, hot predicted yield, %	HOT%	.0225	2.81



TABLE 15. OBSERVED VARIATION ( $R^2$ ) IN TOTAL YIELD (% SIDE WEIGHT BASIS) EXPLAINED BY COMBINATIONS OF USDA YIELD GRADE FACTORS

Independent variable	$R^2$	RSD (%)
EAFAF	.5905	3.28
EAFAF, EREA	.6569	2.76
EAFAF, EREA, KPH	.6853	2.54
EAFAF, EREA, KPH, HCW	.7029	2.40
EAFAF, EREA, KPH, HCW, EFAT	.7038	2.40
EAFAF, EREA, KPH, HCW, EFAT, SEX	.7043	2.41

TABLE 16. OBSERVED VARIATION ( $R^2$ ) IN TOTAL YIELD (% SIDE WEIGHT BASIS) EXPLAINED BY COMBINATIONS OF VIA CAMERA MEASUREMENTS WITH HCW, KPH AND SEX

Independent variable	$R^2$	RSD (%)
FATAVG	.4536	4.41
FATAVG, VREA	.5849	3.36
FATAVG, VREA, KPH	.6255	3.04
FATAVG, VREA, KPH, HCW	.6443	2.90
FATAVG, VREA, KPH, HCW, C21	.6564	2.81
FATAVG, VREA, KPH, HCW, C21, H43	.6678	2.73
FAT2, VREA, KPH, HCW, C21, H43, H11	.6762	2.67
FATAVG, VREA, KPH, HCW, C21, H43, H118, C10	.6819	2.63
FATAVG, VREA, KPH, HCW, C21, H43, H118, C10, H109	.6854	2.61
FATAVG, VREA, KPH, HCW, C21, H43, C10, H60, H72, H120	.6929	2.60

## LITERATURE CITED

- Belk, K.E., J.D. Tatum, H.G. Dolezal, J.B. Morgan, and G.C. Smith. 1996. Meat Composition Measurement: Status of applied research on istrument assessment of composition since completion of the 1994 National Beef Instrument Assessment Planning Symposium. American Society of Meat Science, RMC. 49:172.
- National Live Stock and Meat Board. 1994. The National Beef Instrument Assessment Plan. National Live Stock and Meat Board, Chicago, IL.
- SAS. 1991. SAS Users Guide. SAS Inst. Inc., Cary, NC.
- USDA. 1997. Official Untied States standards for grades of carcass beef. USDA, C & MS, SRA.

## VITA

Clinton Emerson Walenciak

Candidate for the Degree of

Master of Science

Thesis: INSTRUMENT ASSESSMENT OF BEEF CARCASS CUTABILITY  
USING THE CANADIAN COMPUTER VISION SYSTEM OR USDA  
YIELD GRADES

Major Field: Animal Science

### Biographical:

Personal Data: Born in Tulsa, Oklahoma, August 18, 1975, The son of  
John Walenciak and Bessie Waite

Education: Graduated from Oklahoma Union High School, Lenapah,  
Oklahoma, May, 1993; received a Bachelor of Science Degree in  
Animal Science from Oklahoma State University, Stillwater,  
Oklahoma in May, 1997. Completed the Requirements for the  
Master of Science Degree in Animal Science and Food Industry at  
Oklahoma State University in May, 2000.

Professional Experience: Employed by EXCEL Beef, Wichita, Kansas;  
Graduate Research and Teaching Assistantship, Oklahoma State  
University, 1997 to present.

Professional Organizations: American Society of Animal Science,  
American Meat Science Association,