INSTRUMENT ASSESSMENT OF BEEF CARCASS CUTABILITY AND ESTIMATION OF BOXED BEEF VALUE

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CHAPTER I

INTRODUCTION

A value-based system of marketing cattle or beef carcasses relies on the accurate and precise assessment of value on a single animal or carcass rather than on a lot basis. Current methods of assessing beef carcass value (USDA Yield and Quality grades) are subjective and must be evaluated under extreme time constraints. Therefore, development of carcass evaluation procedures that use objective carcass measurements as an aid or replacement for subjective measures would be beneficial in development of a value-based marketing system. Cross and Whittaker (1992) expressed the need for a functional value-based marketing system as the driving force for development and implementation of an instrument grading system for the beef industry.

In 1989, the Cattlemen's Beef Board funded the Value-Based Marketing Task Force which was formed by the National Cattlemen's Association and the Beef Industry Council (Cattlemen's Beef Board, 1990). Task force findings indicated that an instrument grading system was necessary because cattle producers are not confident in subjective measurement of value.

Work had already begun on an objective beef grading system prior to formation of the Value-Based Marketing Task Force in 1989. The USDA in conjunction with the National Aeronautics and Space Administration (NASA) identified video image analysis (VIA) as a potential method of objective carcass evaluation in 1979. Subsequently, a system of a camera and computer was developed and used to assess carcass yield and quality parameters at the $12^{th}/13^{th}$ rib interface. Cross *et al.* (1983) conducted this initial research (a cooperative effort of Kansas State University and the U. S. Meat Animal Research Center) and concluded that VIA was a viable means of objective carcass evaluation.

The National Beef Instrument Assessment Plan identified VIA and Total Body Electrical Conductivity (ToBEC) as the top two choices for applied research involving instrument grading (NLSMB, 1994). Total Body Electrical Conductivity has been reported as a successful predictor of carcass lean (Lin *et al.*, 1992, Gwartney *et al.*, 1994, Bell *et al.*, 1995). However, ToBEC technology is not applicable in an on-line situation in a commercial beef conversion facility. Moreover, current ToBEC machines place physical limitations on the product that they may potentially evaluate. Currently, these limitations require modification of a beef side before lean assessment may take place.

In addition to objectivity, instrument grading methods must meet the following guidelines initially set by the National Cattlemen's Association (NCA) Instrument Grading Subcommittee (NCA, 1990): 1) accurate in predicting lean, marbling, and bone maturity, 2) highly repeatable, 3) automated, 4) capable of operating at a rapid speed in extreme industry environments, and 5) tamperproof and easily calibrated. An ideal assessment technology would aid in the transition to a value-based marketing system for the beef industry.

This experiment was conducted as a cooperative effort of researchers from Oklahoma State University, Colorado State University, University of Nebraska, and the United States Department of Agriculture Agricultural Marketing Service. The objectives of this project were as follows:

1) To determine the accuracies of USDA Yield Grade (YG), Total Body Electrical Conductivity (ToBEC), and Video Image Analysis (VIA) when used to predict yields of primal/subprimal cuts from beef carcass sides.
2) To systematically approach the estimation of carcass yields of primal/subprimal cuts by consideration of subjective and objective measures, and the accuracy and precision of each estimation.
3) To combine beef carcass yield information with an existing database for the development of individual subprimal, lean-trim, fat-trim, and bone prediction equations to be used for estimation of boxed beef value.

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CHAPTER II

REVIEW OF LITERATURE

Beef Carcass Composition and Product Yield

Effect of Carcass Weight

Kropf and Graf (1959) examined the effect of carcass weight on boneless beef yield. They discovered that boneless yield decreased and fat content increased in carcasses increasing from 363 to 408 kg of weight. In agreement, many researchers (Murphey *et al.*, 1960, Cole *et al.*, 1962, Brungardt and Bray, 1963) have reported inverse relationships between carcass weight and yield of wholesale and retail cuts.

Allen *et al.* (1968) selected steer carcasses to fill light (227 to 250 kg, n = 40) and heavy (318 to 340 kg, n = 40) weight groups. Results of this experiment indicated that light weight carcasses yielded higher percentages of retail cuts and lower percentages of fat trim than heavy weight carcasses; however, percentage of carcass weight as separable muscle, fat, and bone did not differ. Additionally, Allen *et al.* (1968) noted that 12^{th} rib fat thickness and carcass weight influence the yield of muscle and fat to a greater extent in light weight than in heavy weight carcasses.

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

Effect of Sex-class

Early work (Brown and Branaman, 1934; Kemp *et al.*, 1954; Kropf and Graf, 1959) indicated that steers yield a higher percentage of lean product and less fat in comparison to heifers. Murphey *et al.* (1960) fabricated steers and heifers (n = 185) into bone-in, closely-trimmed (1.27 or .64 cm remaining *s. c.* fat thickness) retail cuts and did not observe yield differences between sex groups. However, steers have been reported to have a higher percentage of bone, resulting in a lower lean to bone ratio (Kropf and Graf, 1959).

May *et al.* (1992) reported estimated carcass percentages of chuck and flank were lower for heifers in comparison to steers; moreover, heifers had higher yields for the loin, rib, and brisket. Chuck roll differences were largest with at least a 1% advantage for steer carcasses. May *et al.* (1992) explained that these differences were due partially to seam fat deposition. This is in agreement with Jones *et al.* (1990) finding that heifer carcasses produced 1.3% more chuck seam fat. Griffin *et al.* (1992) evaluated carcasses from *Bos indicus* cattle and reported increased boneless, square cut chuck yield (%) for steers in comparison to heifers. Knapp *et al.* (1989) compared English and exotic type steers and heifers and reported similar yields for ribeye rolls.

May *et al.* (1992) indicated that estimated major subprimal yields (2.54 to .64 cm fat trim) from the loin and round tended to be higher or equal for heifers when compared to steers. Knapp *et al.* (1989) observed increased strip loin yields (2.54 or 1.27 cm fat trim) for heifers when compared to steers.

Conflicting results have been presented for trials evaluating sex group differences for carcass yield of trimmable fat. Griffin *et al.* (1992) reported that heifer carcasses produce more trimmable fat than steers. Murphey *et al.* (1985) observed increased external fat trim (%) for heifers when compared to steers. The largest differences noted were cod or udder, chuck, and rump fat trim. However, May *et al.* (1992) indicated similar fat yields for steers and heifers.

Effect of Gender

Major cut yields from Holstein steers were compared to beef type steers and heifers (Knapp *et al.*, 1989). At the 2.54 cm fat trim level, they found that Holstein steers had lower major cut yields than did English steers, Exotic steers and heifers, and *Bos indicus* crossbred steers. This yield difference disappeared when external fat was trimmed to .64 cm. Griffin *et al.* (1992) reported Holstein steer carcass yields of boneless cuts from the round, loin, and rib were typically lower than other sex-class/carcass type combinations. Moreover, Gardner *et al.* (1995a) found that beef carcasses yielded 12.0, 6.8, and 6.9% more boxed product than Holstein carcasses when s. c. fat was trimmed to 1.9, 1.27, and .64 cm, respectively.

Individual primal or subprimal differences have been noted between Holstein steer and beef type carcasses (Garcia-de-Siles *et al.*, 1977; Knapp *et al.*, 1989). Carcass yield of untrimmed rib was reported to be higher for Holstein steer carcasses than Hereford steer carcasses (Garcia-de-Siles *et al.*, 1977). However, Knapp *et al.* (1989) discovered that percentage rib was lower for Holstein steers than for beef type cattle when fat was trimmed to either 2.54 or 1.27 cm, but rib yield (%) was not different when fat was trimmed to .64 cm. Additionally, strip loin expressed as a percentage of carcass weight was lower for Holstein steer carcasses when fat was trimmed to either 2.54 or 1.27 cm. Holstein steers produced carcasses with less fat trim (2.54 cm) when compared to beef carcasses; however, when fat was reduced below 2.54 cm Holstein and beef steers had similar yields (Knapp *et al.*, 1989). Moreover, Holstein steers had the highest percentage of bone for this group of carcasses (19.2% vs 16% for beef steers or 15% for heifers). Griffin *et al.* (1992) reported that dairy steers tended to have more bone than *Bos indicus* steers and heifers (2 to 3%) and beef type steers and heifers.

Assessment of Beef Carcass Traits and Yields Using Video Image Analysis

<u>Principles of Video Image Analysis</u>

Video Image Analysis (VIA) is 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 voltages so that areas of light (fat) can be quantitatively differentiated from areas of dark (lean) (Wood *et al.*, 1991). Fisher (1990) describes VIA as a method of creating an electronic "map". The "map" can be interpreted based on pre-set voltage thresholds.

In the most simple form a VIA system is comprised of a single camera and a computer interpretation system. A camera provides a real-time image which may be captured by a frame-grabber board which is now commonly available in personal computers. Pixels are the smallest unit of images that are generated. Common image areas range from an array of 512 x 512 pixels to 640 x 480 pixels. However, technology is moving at a rapid pace and it should be noted that these image areas will soon be outdated. A pixel may be used to create one of 256 levels of light intensity.

Two camera types are available for use in VIA evaluation of beef carcasses (Swatland, 1995). The vidicon tube camera was the first to be used in objective analysis of carcass yield. More recently, charge-coupled device (CCD) cameras have been used.

The advantage of the vidicon tube camera is the lower cost of the camera. A disadvantage of the tube camera may overestimate bright spots which is a problem when the VIA system is used to evaluate intramuscular fat. Additionally, problems may occur when brightness of the surface being evaluated changes.

The CCD cameras use a chip equipped with photodetectors to replace the tube used in the vidicon system. The advantage of a CCD camera is superior color capability which is useful when separating muscle from fat. Unfortunately, CCD cameras are more sensitive for red and infrared light thus causing potential focusing problems not observed with vidicon tube cameras.

Proper lighting enhances the ability of VIA to distinguish fat and muscle. Cross *et al.* (1983) observed that lighting must be even and diffuse, which is usually achieved using reflector plates or fluorescent tubes. The angle of the light source should be such that reflections are minimized.

Evaluation of Carcass Traits

Fat Thickness. Accurate measurement of s. c. fat thickness with video image analysis is often difficult because of carcass disfigurement in the normal flow of a commercial facility. Cross *et al.* (1983) used a VIA system to evaluate 44 beef carcasses. In their study, fat thickness was measured at a point three-quarters of the length of the longissimus muscle from its medial end. The fat thickness was an average of up to 17 individual measurements obtained in a 1.0 cm distance. Cross *et al.* (1983) reported that VIA measured fat thickness was highly correlated (.90 and .89, respectively) with actual and adjusted fat thickness. Moreover, VIA fat thickness was highly correlated (r = -.77) with 9-10-11th rib lean percentage. Wassenberg *et al.* (1986) evaluated 115 steer carcasses using the same system as Cross *et al.* (1983) and reported high correlations between VIA fat thickness and actual or adjusted fat thickness (r = .91 and .85, respectively).

<u>Fat Area.</u> Fat area (cm^2) is evaluated at the 12^{th} rib cut surface and includes *s. c.* fat as well as intermuscular fat. Simple correlations of .63 to .86 have been reported between fat area and single measures of actual or adjusted fat thickness (Cross *et al.*, 1983; Wassenberg *et al.*, 1986). Additionally, percentage fat area, percentage of the total area evaluated by VIA as fat, is highly correlated with *s. c.* fat thickness measurements. The thought process associated with fat area was to better account for both *s. c.* and intermuscular (seam) fat depots.

<u>Ribeye Area.</u> The $12^{th}/13^{th}$ rib interface typically evaluated for carcass yield traits presents potential problems for instrument assessment of the longissimus dorsi muscle area. Difficulty arises as additional muscles (multifidus dorsi, longissimus costarum, spinalis dorsi, and intercostal muscles) are located adjacent to the longissimus dorsi. Jones *et al.* (1995) evaluated a group of 436 beef carcasses and found that 91% of the variation in ribeye area (cm^2) could be explained using the Chiller Assessment VIASCAN® system. Gardner *et al* (1995b) and Borggaard *et al.* (1996) reported that actual ribeye area measurements and VIA ribeye area estimations were highly correlated (r = .95 and .92, respectively).

<u>Lean Area.</u> Lean area includes the longissimus dorsi as well as the adjacent muscles (multifidus dorsi, longissimus costarum, and spinalis dorsi). This value is easily obtained with VIA because separation of individual muscles

is not required. Cross *et al.* (1983) and Wassenberg (1986) indicated that total lean area (cm^2) was highly correlated with ribeye area (cm^2) ($r = .84$ and .86).

Conformation. When both fatness and carcass length are taken into account, a subjective appraisal of muscle may be a useful guide to the anticipated lean yield of a carcass (Kempster and Harrington, 1980; Perry *et al.*, 1991). Video Image Analysis systems used in the United States do not attempt to measure carcass conformation because conformation is not a factor in the USDA Yield Grade equation. In Australia, the Whole Carcass VIASCAN® is used on the harvest-floor to capture and process images of the lateral view of carcass sides to predict saleable carcass yield (Ferguson *et al.*, 1995).

Currently, the most extensive VIA carcass conformation assessment is being evaluated in the European Union. This VIA system is a second generation Beef Carcass Classification centre (BCC-2) and is designed to operate in the normal harvest-floor line using a positioning frame, camera, two computers, and two slide projectors to determine three-dimensional shape (Borggaard *et al.* ,1996). BCC-2 accounted for 93% of the variation in subjective conformation evaluation of approximately 3500 carcasses (Madsen *et al.* 1996 cited in Borggaard *et al.*, 1996).

Marbling Score. Several video image analysis trials have attempted to quantify marbling. Early work by Cross *et al.* (1983) and Wassenberg *et al.* (1986) objectively estimated marbling with VIA. In these experiments, marbling was defined as any piece of fat (to the nearest .01 cm^2) completely surrounded by lean; therefore, intermuscular fat could be included in the measurement. The marbling estimate was expessed in three ways: 1) number of fat particles 2) summation of the area (cm^2) of the fat particles 3) summation of the area (cm^2) of the fat particles expressed as a percentage of the total fat area (cm^2). Cross *et al.* (1983) observed a moderate relationship (r = .52) between marbling estimated as number of fat particles and subjective evaluation of marbling, but when expressed as a percentage of total fat area (cm^2) the relationship became weak (r = .16). Wassenberg *et al.* (1996) quantified marbling by count and area summation and discovered these measures were lowly correlated with committee estimates of marbling (r = .19 and .14, respectively). Currently, VIA is not an effective method of estimating beef carcass marbling.

<u>Evaluation of Carcass Yields</u>

<u>Fat.</u> The 9-10-11th rib section may be removed from a carcass and dissected into tissue components to predict carcass composition (Hankins and Howe, 1946). Cross *et al.* (1983) used VIA measurements to predict separable fat (kg and %) from 9-10-11th rib sections. Total fat area (%) accounted for 60.4% of the variation in kilograms and 80.8% of the variation in percentage of separable fat from 9-10-11th rib sections. Equations for separable fat (kg and %) became more accurate with the addition of rib weight (kg), total lean area (cm^2), and fat thickness (cm) as indicated by R^2 values of .8611 and .8569, respectively. Wassenberg *et al.* (1986) used side weight and the following VIA traits to predict kilograms and percentage of primal cut fat: fat area (cm^2), lean

area (%/100), fat area (%/100), fat particles (no.), and fat thickness (cm). Additionally, USDA Yield Grade factors were used to predict the same dependent variables. Results indicated 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).

Lean. The ultimate goal of instrument assessment is the accurate and precise measurement of carcass cutability or saleable product yield. Various combinations of VIA measured carcass traits have been used as independent variables in equations developed to predict beef carcass yield.

Carcass cutout yields were obtained from a group of 436 beef carcasses from grain-fed cattle to assess the accuracy of Australian VIA technology (VIASCAN®) in predicting carcass saleable yield (Morgan-Jones *et al.*, 1993). Chiller Assessment VIASCAN® measurements of fat thickness and lean area plus median fat depth plus hot carcass weight accounted for 25% of the variation (RSD = 2.03) in carcass saleable yield. Addition of hot carcass weight to the previous equation increased predictive accuracy by 1%. Whole Carcass VIASCAN® was accurate in predicting saleable yield (R^2 = .61; RSD = 1.50); however, when Whole Carcass VIASCAN® measurements were combined with Chiller Assessment VIASCAN® variables accuracy increased by 11% (RSD = 1.27).

Ferguson *et al.* (1995) used Whole Carcass VIASCAN® to predict saleable beef yield (SBY%) in five groups of beef carcasses as follows: (a) for 29 manufacturing cow carcasses, accuracy in predicting SBY% was R^2 = 0.67

and SEE 1.2, (b) for 30 Korean grass-fed carcasses, accuracy in predicting SBY% was R^2 = 0.43 and SEE 1.0, (c) for 30 domestic grain-fed carcasses, accuracy in predicting SBY% was R^2 = 0.60 and SEE = 1.3, (d) for 30 Japanese grass-fed carcasses, accuracy in predicting SBY% was R^2 = 0.69 and SEE = 1.1, and (e) for 30 Japanese grain-fed carcasses accuracy in predicting SBY% was R^2 = 0.39 and SEE = 1.5. Hot carcass weight and P8 fat depth were also used to predict SBY%. The observed variation in SBY% accounted for by Whole Carcass VIASCAN® was higher in comparison to hot carcass weight and P8 fat depth for all carcass groups except Japanese grain-fed carcasses.

The second generation Beef Carcass Classification centre was used to evaluate beef carcass saleable yield by Borggaard *et al.* (1996). They reported an R^2 of .70 for instrument assessment of percentage of carcass saleable meat.

Cross *et al.* (1983) used combinations of VIA measurements of total lean area (cm^2 and %) and total fat area (cm^2 and %) as independent variables in multiple regression equations used to predict either kilograms or percentage of lean in 9-10-11th rib sections from bullock and steer carcasses. Total lean area (cm^2) used in a single variable equation accounted for 76.6% of the variation in lean weight (kg) from 9-10-11th rib sections. Including total fat area (%), rib weight (kg), and fat thickness (cm) as variables in the previous equation increased R^2 x 100 to 93.6%. Cross *et al.* used total lean area (%) to predict percentage lean from 9-10-11th rib sections with R^2 = .8160. Accuracy in prediction of lean (%) from rib sections was maximized with an equation using total lean area (cm^2) and total fat area (cm^2), R^2 = .89

One-hundred-fifteen steer carcasses were evaluated using VIA and subsequently fabricated into closely-trimmed subprimals. Wassenberg *et al.* (1986) developed prediction equations using side weight, lean area (cm^2), fat area (%/100), lean area (%/100), and color lightness to predict kilograms and percentage carcass primal lean. Kilograms primal lean were predicted more accurately (R^2 = .9563) than percentage primal lean (R^2 = .4636).

Gardner *et al.* (1995b) evaluated the ability of VIA to predict beef side yields of selected boneless, closely-trimmed subprimals. Equations accounted for 21 to 81% of the variation in closely-trimmed subprimal weight and 17 to 69% of the variation in subprimal yield expressed as a percentage of side weight. These results indicated that certain VIA variables in combination with specific rough primal weights were reasonably accurate for predicting yield weights for most subprimals as well as the percentage yields of the gooseneck, ribeye roll, and strip loin. Additionally, VIA fat thickness and ribeye area were used to successfully predict side lean weight (R^2 = .78; Gardner *et al.*, 1995b).

Application of Video Image Analysis

Video Image Analysis is currently being used experimentally in the United States and abroad to predict carcass measurements and saleable yield. This method of objective measurement is non-invasive and relatively economical.

In addition to assessment of beef carcass yield, VIA has been used to quantify fat and lean in boneless fresh and cured meats (Newman, 1984a). Newman developed prediction equations for lipid content of bacon, beef, ham, and pork with residual standard deviations (g/100g) of 1.46, 2.57, 0.93, and 1.13, respectively.

Total Body Electrical Conductivity

Principles of Total Body Electrical Conductivity

Total body electrical conductivity (ToBEC), also referred to as electromagnetic scanning, is based on differences in resistance and capacitance of lean and fat tissues in the carcass. Electromagnetic measurements are reliable, but they depend on each carcass being passed through the instrument in a consistent position and temperature (National Live Stock and Meat Board, 1994).

The ToBEC instrument consists of a plexiglass tube surrounded by a coil of copper wire. The tube is encased in a stainless steel cabinet and when current (2.5 megahertz) is applied to the coil an electromagnetic field is created. Beef carcass components absorb energy from the coil as they are conveyed through the chamber. Funk (1991) describes the ToBEC measurement as neither impedance nor conductivity, but a measure of energy absorption in the presence of an electromagnetic field calibrated internally to match the response of a conductivity sensing element. Since the fat-free mass is 20 times more conductive than the fat, the conductivity index is highly correlated with the lean tissue mass (Forrest, 1995).

This non-invasive measure of carcass composition was originally developed for use in pigs (Domermuth *et al.*, 1973) and has been used to determine lean body mass in humans (Boileau, 1986; Presta *et al.*, 1987; Van Loan *et al.*, 1987). Mersmann *et al.* (1976) used electromagnetic scanning to predict live animal or carcass composition in swine with little success.

Evaluation of Carcass Yields

Lean. Lean content of carcasses from red meat species may be accurately assessed with the ToBEC instrument. Berg *et al.* (1994) accurately predicted pork carcass lean percentage in a commercial environment using electromagnetic measures (R^2 = .863, RSD = 2.05%). In a separate experiment, Berg *et al.* (1994) developed a regression equation for prediction of lamb carcass lean percentage with an R^2 of .787 and a RSD of 1.39%.

The Pig Research and Development Corporation, Meat Research Corporation, and CSIRO Meat Research Corporation in a cooperative effort conducted two studies to evaluate the ability of ToBEC to determine yield in pork, lamb and mutton carcasses, and beef sides. Residual standard deviations for pork carcasses (Ferguson and Eustace, 1991) and for lamb, mutton and beef sides (Ferguson and Eustace, 1993) were 2.77, 2.76, 2.34, and 1.33%, respectively. For comparison, combinations of carcass/side weight plus measures of fat depth were used to predict the same endpoint with residual standard deviations of 2.73, 2.95, 2.55, and 1.57% for pork, lamb, and mutton carcasses, and beef sides, respectively.

Cutout yield of 66 beef carcasses and 19 forequarters was evaluated by electromagnetic scanning by Koch and Varnadore (1976). Koch and Varnadore reported R^2 values of .465, .644, and .591 for equations predicting trimmed primal cut weight using scan information from the forequarter, hindquarter, and beef side, respectively. Ninety to 96% of the variation of trimmed primal cut weight was accounted for when untrimmed primal weight and beef quarter length were added to the equations.

Gwartney *et al.* (1992) reported ToBEC can account for 85 to 90% of the variation in lean in beef forequarters, hindquarters, and primal cuts. Gwartney *et al.* (1994) used ToBEC (peak phase) , length, temperature, weight, and $12^{th}/13^{th}$ rib fat thickness to predict weight of percentage of lean in modified forequarters (foreshank, brisket, and ventral plate removed), hindquarters, and rounds, loins, ribs, and chucks. Prediction equations accounting for the hindquarter or forequarter of steers accounted for 84 to 93% of the variation in lean weight of beef sides and quarters, and 71 to 93% of the variation in lean weight of primal cuts. Additionally, Gwartney *et al.* (1994) developed equations that accounted for 61 to 75% of the variation in percentage of lean in sides and quarters and 48 to 65% of the variation in lean percentage in primal cuts. Bell *et al.* (1995) modified the configuration of beef sides to allow them to pass through the ToBEC instrument and predicted weight of beef side lean with a R^2 of .936 and a RSD of 2.44 kg.

Application of Total Body Electrical Conductivity

In Australia, ToBEC technology has been successfully introduced in eleven abattoirs for the on-line determination of chemical-lean content in boxed beef (National Live Stock and Meat Board, 1994). Allen (1995) reported that industrial applications of ToBEC for predicting the chemical-lean percentage of boxed boneless beef in Australia have been highly successful at rates of 1200 boxes per hour.

Experimental results for prediction of boxed beef yields from scans of hindquarters and modified forequarters indicate that ToBEC is an accurate estimator; however, existing machines will not accommodate these beef carcass components. Additionally, advantages of the non-invasive ToBEC technology may be offset by the costs of equipment and installation ($300,000 to $500,000).

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CHAPTER III

ESTIMATION OF BEEF CARCASS CUTABILITY USING VIDEO IMAGE ANALYSIS, TOTAL BODY ELECTRICAL CONDUCTIVITY OR YIELD GRADE

ABSTRACT

Video Image Analysis (VIA), Total Body Electrical Conductivity (ToBEC), and Yield Grade evaluation were used to estimate beef carcass cutability. Two-hundred-forty beef carcasses (120 steers and 120 heifers) were selected to fill a 2 x 6 x 2 matrix of sex-class (steer or heifer), Yield Grade (YG1, YG2A, YG2B, YG3A, YG3B, YG4), and carcass weight-class (light, 249.5 to 340.1 kg; heavy, 340.2 to 430.9 kg). Carcasses were sequentially converted to boneless boxed beef product at three s. c. fat trim levels (2.54, 1.27, and .64 cm).

USDA Graders accounted for 59% of the variation in boxed beef yield (.64 cm fat trim) with on-line application of USDA Yield Grades. Committee application of USDA Yield Grades with measurement devices and without time constraints improved the accuracy of this equation (R^2 x 100 = 82%).

Video Image Analysis and ToBEC carcass measures accounted for 45% and 36% of the variation in boxed beef yield (.64 cm fat trim), respectively. Substituting on-line VIA measures of fat thickness and ribeye area in the USDA

Yield Grade equation explained 57% of the variation in cutability (.64 cm fat trim). Total Body Electrical Conductivity substituted for ribeye area in the USDA Yield Grade equation improved accuracy (R^2 = .88) for prediction of boxed beef yield (.64 cm fat trim).

Introduction

Currently, interest is increasing in the development of cattle marketing systems that assess value on an individual animal basis (value-based marketing). Therefore, a method of identifying individual carcass red meat yield is necessary to aid in determining value.

The evaluation technique used to determine yield must be able to perform on-line in a commercial setting without disrupting the normal product flow. Two technologies that may satisfy these requirements have been identified in the National Beef Instrument Assessment Plan (National Live Stock and Meat Board, 1994): Video Image Analysis (VIA) and Total Body Electrical Conductivity (ToBEC).

Video Image Analysis is a non-invasive procedure that utilizes one or more video cameras in unison with image processing software to evaluate carcass characteristics and predict carcass cutability. Cross *et al.* (1983) first used VIA to predict the composition of 9-10-11th rib sections obtained from 44 steer carcasses. When VIA variables, total lean area (cm^2) and total fat area (cm^2) were combined with rib weight and fat thickness, a coefficient of determination of 93.6% was observed for kilograms of lean. The coefficient of determination was 84.2% for the best non-VIA variable prediction equation. Wassenberg *et al.* (1986) determined primal lean cut-out from 115 steer carcasses and evaluated the ability of VIA variables to predict carcass red meat yield: total kilograms primal lean (coefficient of determination = 95.63%) and percent primal lean (coefficient of determination = 46.36%).

Gwartney *et al.* (1992) reported that 85 to 90% of the variation in lean content of steer beef quarters and primals can be accounted for with electromagnetic scanning. Results from a second trial conducted by Gwartney *et al.* (1994), indicated that 75 or 80% of the variation in percentage lean of steer or heifer sides, respectively, could be accounted for with electromagnetic scanning.

Yield Grades accurately and precisely categorize beef carcasses according to their expected yields of boneless, closely trimmed (0.64 cm maximum fat thickness) primal cuts if appropriate factors are accurately and precisely assessed and applied to the USDA Yield Grade equation (USDA, 1965). However, the USDA equation does not attempt to predict primal cut yields when trimmed to variable s. c. fat depths.

The objective of this experiment was to determine, in a commercial beef conversion complex, the accuracy and precision of VIA, ToBEC, and the USDA Yield Grade equation in determining red meat yield of steer and heifer carcasses of varying Yield Grades trimmed to either 2.54, 0.64, or 0.00 cm s. c. fat thickness.

Materials and Methods

USDA graders assigned a USDA Yield Grade (nearest 1.0 Yield Grade) to carcasses presented at chain speeds of 350 to 400 carcasses per hour as a portion of the daily plant production. Immediately following Yield Grade assignment, carcasses were evaluated by a Video Image Analysis (VIA) system (Figure 1) operated by plant personnel at normal chain speed. Video Image Analysis variables were obtained at the 12^{th} rib interface at chain speed. These VIA motion variables included: subcutaneous fat thickness (MFT), ribeye area (MLA), and fat area (MFA, subcutaneous and intermuscular fat).

Following evaluation by USDA graders and VIA, 240 beef carcasses (steers n = 120, heifers n = 120) were selected by university carcass evaluation experts and plant management personnel from normal daily production in a commercial beef conversion facility to fill a 2 x 6 x 2 matrix of sex-class (steer or heifer), USDA final Yield Grade (YG1, YG2A, YG2B, YG3A, YG3B, YG4), and side weight (light, 249.5 to 340.1 kg; heavy, 340.2 to 430.9 kg). Selected carcasses were placed on a stationary rail with adequate lighting to evaluate grade characteristics. At this time, a team of 3 carcass evaluation experts (2 from universities and 1 from USDA) assessed carcass grade characteristics. The team was allowed to use measuring aids (grids and s. c. fat probes) as each member independently evaluated each carcass. The experts were given whatever time necessary to make their evaluations. The averages of the three experts' measurements (adjusted fat thickness, EFT; ribeye area, ERA) were recorded along with hot carcass weight as actual carcass measurements. Experts evaluated kidney, pelvic, and heart fat (KPH) percentage subjectively (EKP), and actual KPH (AKP) was calculated from weights obtained in subsequent side fabrication. The actual Yield Grade was calculated using EFT, ERA, ACW, and AKP. Experts' Yield Grade was determined substituting EKP for AKP in the previous calculation. The evaluation team independently assessed carcass lean and bone maturity, and intramuscular fat for each carcass to determine USDA Quality Grade. As with Yield Grade factors, each of the Quality Grade factors were recorded as an average of the carcass evaluation team and then used to determine the actual Quality Grade. Before carcass selection was finalized, experts' examined the carcass for defects in workmanship that might influence red meat yield.

Selected carcasses were evaluated with VIA while at rest. Evaluation site was the same as for motion measurement. Stationary VIA variables obtained were: subcutaneous fat thickness (SFT), ribeye area (SLA), fat area (SFA, subcutaneous and intermuscular fat), loin height (SLH), and loin width (SLW).

Prior to fabrication, red meat yields of right sides were estimated by a Total Body Electrical Conductivity (ToBEC) unit (Figure 2) located adjacent to the temporary conversion table. Hindquarters with kidney and pelvic fat remaining were passed through the ToBEC chamber for initial evaluation (H1PEAK). Kidney and pelvic fat was removed before hindquarters were passed through the ToBEC unit for final evaluation (H2PEAK). The forequarters were separated into beef bands (rib and plate) and cross cut chucks and evaluated individually (BPEAK and CPEAK).

Upon completion of carcass evaluation, the right side of each carcass was fabricated (approximately 10 per day over a 5 week period) by a team of plant trainers following progressive HRI and Institutional Meat Purchase Specifications (IMPS; USDA, 1990) guidelines. Sides were partitioned into the following subprimals and trim products: shoulder clod (IMPS 114), chuck roll (IMPS 116A), ribeye roll (IMPS 112A), strip loin (IMPS 180), tenderloin (IMPS 189A), top butt (IMPS 184), gooseneck round (IMPS 170), inside round (IMPS 168), knuckle (IMPS 167), brisket (IMPS 120), pectoral, chuck tender (IMPS 116B), boneless short rib, bottom sirloin flap (IMPS 185A), bottom sirloin ball tip (IMPS 185B), bottom sirloin tri-tip (IMPS 185C), inside skirt (IMPS 121D), outside skirt (IMPS 121C), blade meat (IMPS 109B), and lean trim (80% and 50%). Subcutaneous fat was sequentially removed (2.54, 0.64, and 0.00 cm maximum) from appropriate subprimals and component weights were obtained and recorded by University personnel after each step. Upon completion of fabrication, 50% and 80% lean trim were combined and passed through the ToBEC for peak value measurement (LPEAK).

A 2 x 6 x 2 matrix of sex-class (steer vs. heifer), Yield Grade (YG1, YG2A, YG2B, YG3A, YG3B, and YG4), and weight-class (light vs. heavy) was utilized. The main effects of sex-class, Yield Grade, and weight-class as well as appropriate interactions were tested for significance ($P < .05$) using the GLM procedure of SAS (SAS, 1986). Least squares means for carcass characteristics and cutability endpoints were determined using the GLM procedure of SAS (SAS, 1986). Simple correlations were calculated for VIA, ToBEC, and actual/estimated carcass variables using the CORR procedure of SAS (SAS, 1986). Carcass characteristics evaluated by USDA graders, experts', VIA, and ToBEC along with recorded weights were used as independent variables in the STEPWISE procedure of SAS (SAS, 1986) to generate multiple regression equations to predict red meat yield at either 2.54, 0.64, or 0.00 cm fat-trim levels.

Results and Discussion

Interactions for the main effects of Yield Grade, sex-class, and weight-class were not significant ($P > .05$), with the exception of a Yield Grade x weight-class interaction for percentage bone ($P < .05$). Therefore, least squares means are reported for the main effects.

Least squares means for carcass grade characteristics stratified by experts' Yield Grade (EYG) are presented in Table 1. Hot carcass weights were similar ($P > .05$) for all experts' Yield Grade categories. Actual fat thickness (AFT) increased ($P < .01$) with each increase in experts' Yield Grade with the exception of EYG2A and EYG2B. Adjusted fat thickness increased ($P < .01$) and ribeye area (REA) decreased ($P < .01$) as experts' Yield Grade increased. Estimated kidney, pelvic, and heart fat percentage was greatest ($P < .01$) for EYG3B and EYG4. Actual kidney, pelvic, and heart fat percentage was lowest ($P < .01$) for EYG1 and EYG2. By design actual Yield Grade (AYG) and experts' Yield Grade means were each within the specified Yield Grade categories 1, 2A, 2B, 3A, 3B, and 4 and were different (P < .01). Marbling scores for EYG3A, EYG3B, and EYG4 were all in the "small" category and more desirable (P < .01) than EYG1, EYG2A, and EYG2B.

Carcass grade characteristics for steers and heifers are listed in Table 2. Steer carcasses were heavier (P < .01) than heifer carcasses. When compared to heifers, steer carcasses had decreased (P < .01) values for the following traits: actual fat thickness, adjusted fat thickness, ribeye area, experts' estimation and actual percentage of kidney, pelvic, and heart fat, actual Yield Grade and marbling score. However, experts' Yield Grade was similar (P > .05) for steer (2.96) and heifer (3.01) carcasses.

Table 3. displays grade characteristics for light and heavy carcasses. As expected, the heavy weight-class carcasses were heavier (P < .01) than light weight-class carcasses. Lower (P < .05) values for light weight-class carcasses were observed for actual and adjusted fat thickness, ribeye area, marbling score and experts' estimation of kidney, pelvic, and heart fat percentage. Yield Grade (EYG and AYG) was not different (P > .05) when carcasses were partitioned by weight-class.

Least squares means for cutability endpoints stratified by EYG are presented in Table 4. A yield by weight-class interaction (P = .012) was observed for side percentage of bone; therefore, bone (%) is listed for light and heavy weight-class carcasses. Subcutaneous fat-trim at all levels (2.54, 0.64, and 0.00 cm) increased (P < .01) progressively with experts' Yield Grade category. Conversely, the percentage of side boxed beef decreased (P < .01) with each increase in experts' Yield Grade. The percentage of 80% lean trim was highest ($P < .01$) for EYG1 and lowest ($P < .01$) for EYG3B and EYG4 when s. c. fat was trimmed to either 2.54 or 0.64 cm. However, when *s. c.* fat was completely removed, EYG4 had the lowest ($P < .01$) percentage of 80% lean trimmings. The percentage of 50% lean trimmings followed a similar pattern across all fat-trim levels. The lowest ($P < .01$) percentages of 50% lean trimmings were observed for EYG1, EYG2A, and EYG2B.

Sex-class and weight-class cutability endpoints are presented in Tables 5 and 6, respectively. Steer and light weight carcasses had a higher ($P < .01$) percentage of bone than heifer carcasses. Heifer and heavy weight carcasses produced more ($P < .01$) fat-trim than steer or light weight carcasses at each of the 3 levels measured. As a result, boxed beef yield was lower ($P < .01$) for heifers and heavy carcasses than for steer and light carcasses. Regardless of fat-trim level, steer and light carcasses produced more ($P < .01$) 80% lean-trim than heifers or heavy weights. Fifty percent lean-trim was similar ($P > .05$) for sex-class at all fat-trim levels, but heavy carcasses produced more ($P < .05$) than light.

Instrument measurement least squares means stratified by experts' Yield Grade are reported in Table 7. No differences ($P > .05$) for ToBEC peak value occurred between experts' Yield Grade categories for the beef band or lean trim. However, hindquarter (KP in and KP out) peak values decreased ($P < .01$) with each increase in experts' Yield Grade. The highest ($P < .01$) peak value for the cross-cut chuck was observed for EYG1 and lowest ($P < .01$) for EYG4.

Stationary VIA measures of ribeye area and loin width did not differ ($P > .05$) across EYG. Motion fat area ranged from 30.94 cm^2 (EYG1) to the largest ($P < .01$) area of 66.76 cm^2 for EYG4. Expert Yield Grade 4 also displayed the largest ($P < .01$) stationary fat area. Fat thickness measured by VIA on-line was thinnest ($P < .01$) for EYG1 and increased ($P < .01$) with each additional whole Yield Grade. Similar results were noted for stationary fat thickness measures, but EYG2A was not different ($P < .01$) from EYG1. Motion VIA ribeye area values were different ($P < .01$) for EYG with noticeably smaller ribeyes in EYG3B. Stationary VIA measures of loin height were tallest ($P < .01$) for EYG1, 2A, and 2B with the shortest ($P < .01$) being recorded for EYG4. Sex-class least squares means for ToBEC peak values and VIA are given in Table 8. Peak values for all ToBEC variables were higher ($P < .01$) for steers than heifers. All VIA fat measurements with the exception of stationary fat thickness, were lower ($P < .05$) for steers than heifers. Ribeye areas measured by VIA at rest were 8 cm^2 larger ($P < .01$) in steer carcasses vs. heifers. Remaining VIA muscling indicators did not differ ($P > .05$) for the main effect of sex-class. ToBEC peak values were higher ($P < .05$) lean trim both hindquarter variables and beef band in heavy weight carcasses, but lower for cross-cut chuck (Table 9). Video Image Analysis measurements of heavy and light carcasses indicated an increase ($P < .05$) in all muscling indicators and stationary fat area for heavy carcasses. Other VIA indicators of fat did not differ ($P > .05$) for weight-class.

Simple correlation coefficients between instrument measurements, Yield Grade, carcass traits, boxed beef yield, lean-trim, fat-trim, and bone are presented in Tables 10 and 11. Based on simple correlation coefficients with the percentage of boxed beef at 0.64 cm fat-trim (PLQ), EYG and AYG more accurately predicted yield than did USDA graders (-.91 vs. -.77, Table 10). This suggests that the current USDA Yield Grade system is an accurate predictor of boxed beef yield and inaccurate assignment of Yield Grades may result from extreme on-line conditions. In Table 11. evaluation of objective measures of boxed beef yield indicate that fat area measured on-line and at rest (MFA and SFA) were almost equally successful in predicting boxed beef yield at 0.64 cm fat-trim (correlation coefficients of -.67 and -.66, respectively). However, motion fat thickness was superior to fat thickness measured at rest in prediction of this same cutability endpoint (-.64 vs. -.54, Table 11). ToBEC peak values more closely predicted boxed beef yield at 0.64 cm fat-trim when obtained from the hindquarter with the KP in or out (correlation coefficients of .60 and .58, Table 11). The cross-cut chuck was the most effective indicator obtained from the forequarter with a correlation coefficient of .45 (Table 11).

Instrument measurements, Yield Grade factors, and actual, experts' or USDA Yield Grade were used individually as an independent variable for predicting boxed beef yield at .64 cm *s. c.* fat trim (Table 12). As expected, actual and experts' Yield Grade accounted for the most variation in yield (R^2 = .83 and .82, respectively). The most accurate variables from the remaining categories are as follows: Experts' fat thickness (R^2 = .72), USDA Yield Grade (R^2 = .59), VIA motion fat area (R^2 = .45), and ToBEC hindquarter peak value KP out (R^2 = .36).

Multiple regression equations, substituting VIA measurements for USDA Yield Grade factors to predict percent boxed beef at 0.64 cm fat-trim are presented in Table 13. Using experts' factors for three of the four Yield Grade factors, to compute predicted yields of boxed beef in a four-variable equation, resulted in explanation of 85.1% of the observed variation in percent boxed beef at 0.64 cm fat-trim. A three-variable equation combining three of those same four experts' factors but not including experts' KPH explained 79.7% of the variation in PLQ, a 5.4% decrease in predictive accuracy. An equation using only instrument obtained variables (MFT, MLA, MFA, HCW) accounted for 53.5% of the variation in boxed beef yield (0.64 cm fat-trim). Substituting KPH for motion fat area in the previous equation increased accuracy of boxed beef prediction (0.64 cm) by 5.3%. Additionally, this value was explained with 85.5% accuracy using EFT, EKP, HCW, and HQO. When EFT, EKP and HCW were combined with the ToBEC muscling indicator of HQO divided by side weight, 88.1% of the variation in PLQ was explained. This equation was superior for all combinations of instrument measurements, expert evaluations, and carcass weight.

Four-variable equations combining USDA Yield Grade factors (estimated and measured), and VIA measures (on-line or stationary) for predicting yield of boxed beef (0.64 cm fat-trim) are presented in Table 14. The equation which best predicted red meat yield (R^2 = .8635) was a combination of EFT, REA, AKP, and HCW. When EKP was substituted for AKP, the R^2 x 100 was reduced 1.2%. Substitution of VIA variables (MFT and MLA) for EFT and REA reduced equation accuracy by 28.9%. A further reduction in predictive accuracy (9%) was observed when VIA variables obtained at rest (SFT and SLA) were substituted for MFT and MFA. ToBEC variables could only substitute for REA in these four-variable equations (Table 15). The best predictors were hindquarter peak value KP in (R^2 = .8724) and HQI divided by side weight (R^2 =.8807).

Implications

Objective methods of assessing beef carcass cutability are essential for the success of any value-based marketing system. This study indicates that the current USDA Yield Grading system is a valid indicator of cutability if equation variables are accurately assigned. However, on-line conditions hinder assessment of Yield Grade by USDA graders as they must assess Yield Grade and Quality Grade and apply their stamp to a carcass in a period of 7 to 20 seconds. When VIA estimates of current Yield Grade factors (motion fat thickness and motion loin area) are substituted into the Yield Grade equation, accuracy is improved over USDA graders' on-line estimates. Moreover, if motion loin area is used in combination with a USDA grader estimate of adjusted fat thickness, the accuracy of the Yield Grade approaches Yield Grades determined under ideal conditions. Although ToBEC measurements must currently be obtained off-line, substitution of ToBEC muscling indicators (hindquarter, kidney and pelvic fat present and this value divided by side weight) for ribeye area in the Yield Grade equation improves predictive accuracy beyond Yield Grades applied under ideal conditions by an expert committee. Currently, VIA may be used in conjunction with USDA grader estimates to improve accuracy of Yield Grade assessment. Although ToBEC technology is not applicable in an on-line situation for beef carcass assessment, future improvements in the technology may deem ToBEC a valuable instrument.

TABLE 1. CARCASS GRADE CHARACTERISTICS STRATIFIED BY EXPERTS' YIELD GRADE[a].

	Experts' Yield Grade						
Grade characteristic	1	2A	2B	3A	3B	4	P
Hot carcass weight, kg	338.92	341.10	335.90	337.99	342.62	339.65	.74
Fat thickness, 12^{th} - 13^{th} ribs, cm	.65[c]	.89[d]	1.00[d]	1.43[e]	1.53[e]	2.17[f]	<.01
Adjusted fat thickness, 12^{th} -13^{th} ribs, cm	.79[c]	1.05[d]	1.27[e]	1.60[f]	1.74[g]	2.30[h]	<.01
Ribeye area, cm^2	101.26[c]	91.69[d]	87.22[e]	83.34[f]	78.64[g]	73.83[h]	<.01
Experts' kidney/pelvic/heart fat, %	2.09[c]	2.16[cd]	2.32[d]	2.34[d]	2.66[e]	2.64[e]	<.01
Actual kidney/pelvic/heart fat, %	2.67[c]	2.79[c]	3.11[de]	2.93[cd]	3.35[e]	3.40[e]	<.01
Experts' Yield Grade	1.51[c]	2.27[d]	2.70[e]	3.24[f]	3.71[g]	4.47[h]	<.01
Actual Yield Grade	1.62[c]	2.39[d]	2.86[e]	3.36[f]	3.85[g]	4.62[h]	<.01
Marbling score[b]	375.96[c]	393.76[c]	394.44[c]	429.56[d]	433.88[d]	457.70[d]	<.01

[a] Experts' Yield Grade was computed using experts' adjusted preliminary Yield Grade, expert's ribeye area, experts' estimated percentage kidney/pelvic/heart fat and actual carcass weight.
[b] Slight = 300, Small = 400.
[cdefgh] Means in the same row with a common superscript are not different (P > .05).

TABLE 2. CARCASS GRADE CHARACTERISTICS STRATIFIED BY SEX-CLASS.

	Sex-class		
Grade characteristics	Steer	Heifer	P
Hot carcass weight, kg	343.57	335.15	<.01
Fat thickness, 12th - 13th ribs, cm	1.17	1.39	<.01
Adjusted fat thickness, 12th -13th ribs, cm	1.36	1.56	<.01
Ribeye area, cm^2	84.69	87.30	<.01
Experts' kidney/pelvic/heart fat, %	2.25	2.49	<.01
Actual kidney/pelvic/heart fat, %	2.79	3.29	<.01
Experts' Yield Grade	2.96	3.01	.09
Actual Yield Grade	3.07	3.17	<.01
Marbling score[a]	394.19	434.24	<.01

[a]Slight = 300, Small = 400.

TABLE 3. CARCASS GRADE CHARACTERISTICS STRATIFIED BY WEIGHT-CLASS[a].

Grade characteristics	Weight-class Light	Heavy	P
Hot carcass weight, kg	312.62	366.10	<.01
Fat thickness, 12^{th} - 13^{th} ribs, cm	1.24	1.32	.048
Adjusted fat thickness, 12^{th} -13^{th} ribs, cm	1.42	1.50	.017
Ribeye area, cm^2	80.51	91.49	<.01
Experts' kidney/pelvic/heart fat, %	2.26	2.48	<.01
Actual kidney/pelvic/heart fat, %	2.96	3.12	.064
Experts' Yield Grade	2.97	3.00	.420
Actual Yield Grade	3.11	3.12	.660
Marbling score[b]	401.12	427.32	<.01

[a] Light: hot carcass weight < 340.2 kg, Heavy: hot carcass weight ≥ 340.2 kg.
[b] Slight = 300, Small = 400.

TABLE 4. CARCASS CUTABILITY ENDPOINTS STRATIFIED BY EXPERTS' YIELD GRADE[a].

	Experts' Yield Grade						
Cutability endpoint[b]	1	2A	2B	3A	3B	4	P
Bone:							
Light[c]	15.03	14.54	13.98	13.97	13.80	13.30	.012[d]
Heavy[c]	13.77	14.37	14.28	13.44	13.17	12.90	
Fat-trim, 2.54 cm	11.22^{e}	12.75^{f}	13.89^{g}	15.17^{h}	16.35^{i}	18.13^{j}	<.01
Fat-trim, .64 cm	13.02^{e}	14.99^{f}	16.41^{g}	18.27^{h}	19.61^{i}	22.01^{j}	<.01
Fat-trim, 0 cm	14.68^{e}	16.83^{f}	18.34^{g}	20.30^{h}	21.64^{i}	24.14^{j}	<.01
Boxed beef, 2.54 cm fat-trim	56.42^{e}	55.17^{f}	54.30^{g}	53.31^{h}	52.50^{i}	51.20^{j}	<.01
Boxed beef, .64 cm fat-trim	54.03^{e}	52.37^{f}	51.22^{g}	49.60^{h}	48.62^{i}	46.68^{j}	<.01
Boxed beef, 0 cm fat-trim	50.76^{e}	48.98^{f}	47.76^{g}	46.14^{h}	45.11^{i}	43.21^{j}	<.01
80% lean trim, 2.54 cm fat-trim	11.51^{e}	11.15^{f}	11.21^{f}	11.14^{f}	10.87^{g}	10.67^{g}	<.01
80% lean trim, .64 cm fat-trim	11.57^{e}	11.23^{f}	11.28^{f}	11.20^{f}	10.94^{g}	10.75^{g}	<.01
80% lean trim, 0 cm fat-trim	13.19^{e}	12.78^{f}	12.81^{f}	12.63^{ef}	12.42^{g}	12.09^{h}	<.01
50% lean trim, 2.54 cm fat-trim	6.46^{e}	6.47^{e}	6.46^{e}	6.69^{f}	6.80^{fg}	6.92^{g}	<.01
50% lean trim, .64 or 0 cm fat-trim	6.98^{e}	6.96^{e}	6.96^{e}	7.23^{f}	7.34^{fg}	7.49^{g}	<.01

[a]Experts' Yield Grade was computed using experts' adjusted preliminary Yield Grade, expert's ribeye area, experts' estimated percentage kidney/pelvic/heart fat and actual carcass weight.
[b]Expressed as a percentage of aggregate side weight.
[c]Light: hot carcass weight < 340.2 kg, Heavy: hot carcass weight ≥ 340.2 kg.
[d]Probability of expert's Yield Grade x weight-class effect.
[efghij]Means in the same row with a common superscript are not different ($P > .05$).

TABLE 5. CARCASS CUTABILITY ENDPOINTS STRATIFIED BY SEX-CLASS.

	Sex-class		
Cutability endpoint	Steer	Heifer	P[a]
Percent fat-trim, 2.54 cm.	13.57	15.60	<.01
Percent fat-trim, .64 cm.	16.27	18.50	<.01
Percent fat-trim, 0 cm.	18.21	20.44	<.01
Percent boxed beef, 2.54 cm. fat-trim	54.11	53.53	<.01
Percent boxed beef, .64 cm. fat-trim	50.83	50.02	<.01
Percent boxed beef, 0 cm. fat-trim	47.40	46.58	<.01
Percent 80% lean trim, 2.54 cm. fat-trim	11.21	10.98	<.01
Percent 80% lean trim, .64 cm. fat-trim	11.28	11.05	<.01
Percent 80% lean trim, 0 cm. fat-trim	12.77	12.54	<.01
Percent 50% lean trim, 2.54 cm. fat-trim	6.67	6.60	.23
Percent 50% lean trim, .64 or 0 cm. fat-trim	7.17	7.15	.72

[a]Probability of a sex-class effect.

TABLE 6. CARCASS CUTABILITY ENDPOINTS STRATIFIED BY WEIGHT-CLASS[a].

	Weight-class		
Cutability endpoint	Light	Heavy	P[b]
Percent fat-trim, 2.54 cm.	14.16	15.01	<.01
Percent fat-trim, .64 cm.	16.93	17.84	<.01
Percent fat-trim, 0 cm.	18.85	19.80	<.01
Percent boxed beef, 2.54 cm. fat-trim	54.01	53.62	<.01
Percent boxed beef, .64 cm. fat-trim	50.64	50.21	<.01
Percent boxed beef, 0 cm. fat-trim	47.22	46.76	<.01
Percent 80% lean trim, 2.54 cm. fat-trim	11.17	11.02	.015
Percent 80% lean trim, .64 cm. fat-trim	11.24	11.09	.018
Percent 80% lean trim, 0 cm. fat-trim	12.74	12.57	.013
Percent 50% lean trim, 2.54 cm. fat-trim	6.56	6.71	<.01
Percent 50% lean trim, .64 or 0 cm. fat-trim	7.09	7.23	.018

[a]Light: hot carcass weight < 340.2 kg, Heavy: hot carcass weight ≥ 340.2 kg.
[b]Probability of a weight-class effect.

TABLE 7. LEAST SQUARES MEANS FOR VIDEO IMAGE ANALYSIS (VIA) AND TOTAL BODY ELECTRICAL CONDUCTIVITY (ToBEC) MEASUREMENTS STRATIFIED BY EXPERTS' YIELD GRADE[a].

	Experts' Yield Grade						
Instrument measurement	1	2A	2B	3A	3B	4	P
ToBEC peak values:							
beef band	105.02	97.68	99.59	98.76	98.63	95.51	.60
cross-cut chuck	325.63[b]	301.81[c]	286.45[cd]	276.53[d]	269.63[d]	246.36[e]	<.01
hindquarter, (KP in)	467.84[b]	406.59[c]	387.92[c]	356.27[d]	336.90[d]	306.38[e]	<.01
hindquarter, (KP out)	459.76[b]	401.27[c]	380.00[c]	346.70[d]	327.97[d]	297.47[e]	<.01
lean trim	127.34	115.90	117.66	117.49	110.24	104.33	.26
VIA :							
motion fat area, cm^2	30.94[b]	34.25[b]	44.40[c]	46.50[c]	53.87[d]	66.76[e]	<.01
motion fat thickness, cm.	0.95[b]	1.21[c]	1.38[c]	1.75[d]	1.94[d]	2.60[e]	<.01
motion ribeye area, cm^2	99.03[b]	90.72[bc]	98.42[b]	96.87[b]	81.00[d]	82.31[cd]	<.01
stationary fat area, cm^2	29.22[b]	34.80[c]	40.52[d]	46.20[e]	50.07[e]	59.14[f]	<.01
stationary fat thickness, cm.	1.14[b]	1.37[bc]	1.50[c]	1.99[d]	2.14[d]	2.69[e]	<.01
stationary ribeye area, cm^2	95.39	93.95	91.00	89.89	83.77	86.53	.08
stationary loin height, cm	11.54[b]	11.17[b]	11.45[b]	11.14[bc]	10.84[cd]	10.56[d]	<.01
stationary loin width, cm	10.79	10.73	10.23	10.11	10.11	9.58	.06

[a] Experts' Yield Grade was computed using experts' adjusted preliminary Yield Grade, expert's ribeye area, experts' estimated percentage kidney/pelvic/heart fat and actual carcass weight.

TABLE 8. LEAST SQUARES MEANS FOR VIDEO IMAGE ANALYSIS (VIA) AND TOTAL BODY ELECTRICAL CONDUCTIVITY (ToBEC) MEASUREMENTS STRATIFIED BY SEX-CLASS.

	Sex-class		
Instrument measurement	Steer	Heifer	P[a]
ToBEC peak values:			
beef band	104.61	93.78	<.01
cross-cut chuck	307.68	261.12	<.01
hindquarter, (KP in)	389.07	364.91	<.01
hindquarter, (KP out)	379.31	358.42	<.01
lean trim	123.13	107.86	<.01
VIA:			
motion fat area,	44.55	47.69	<.05
motion fat thickness, cm.	1.56	1.72	<.05
motion ribeye area, cm^2	91.61	91.18	.87
stationary fat area,	40.96	45.70	<.01
stationary fat thickness, cm.	1.74	1.87	.18
stationary ribeye area, cm^2	94.08	86.10	<.01
stationary loin height, cm	11.18	11.05	.46
stationary loin width, cm	10.23	10.28	.86

[a]Probability of a sex-class effect.

TABLE 9. LEAST SQUARES MEANS FOR VIDEO IMAGE ANALYSIS (VIA) AND TOTAL BODY ELECTRICAL CONDUCTIVITY (ToBEC) MEASUREMENTS STRATIFIED BY WEIGHT-CLASS[a].

	Weight-class		
Instrument measurement	Light	Heavy	P[b]
ToBEC peak values:			
beef band	86.11	112.28	<.01
cross-cut chuck	307.68	261.12	<.01
hindquarter, (KP in)	328.22	425.75	<.01
hindquarter, (KP out)	320.99	416.73	<.01
lean trim	109.49	121.50	.04
VIA:			
motion fat area,	44.85	47.39	.11
motion fat thickness, cm.	1.67	1.60	.33
motion ribeye area, cm^2	86.73	96.05	<.01
stationary fat area,	41.72	44.93	.03
stationary fat thickness, cm.	1.77	1.84	.40
stationary ribeye area, cm^2	85.81	94.37	<.01
stationary loin height, cm	10.82	11.41	<.01
stationary loin width, cm	9.92	10.59	<.01

[a]Light: hot carcass weight < 340.2 kg, Heavy: hot carcass weight $\geq$ 340.2.
[b]Probability of a weight-class effect.

TABLE 10. SIMPLE CORRELATION COEFFICIENTS BETWEEN CARCASS TRAITS, YIELD GRADE, FAT-TRIM, AND BOXED BEEF ENDPOINTS.

	n	PFO[a]	PFQ[b]	PFZ[c]	PLO[d]	PLQ[e]	PLZ[f]
USDA Yield Grade	224	.70**	.75**	.75**	-.70**	-.77**	-.77**
Adjusted fat thickness, cm	240	.83**	.87**	.87**	-.76**	-.85**	-.85**
Ribeye area, cm^2	240	-.42**	-.45**	-.46**	.59**	.59**	.59**
Estimated KPH, (%)[g]	240	.54**	.50**	.49**	-.52**	-.48**	-.46**
Actual KPH, (%)[g]	240	.62**	.54**	.53**	-.55**	-.48**	-.47**
Hot carcass weight, kg	240	.12	.12	.12	-.09	-.09	-.08
Experts' Yield Grade[h]	240	.81**	.85**	.85**	-.86**	-.91**	-.90**
Actual Yield Grade[i]	240	.83**	.86**	.86**	-.87**	-.91**	-.91**

*P <.01, **P <.001.

[a]PFO: s. c. fat trimmed to 2.54 cm. expressed as a percentage of aggregate side weight.

[b]PFQ: s. c. fat trimmed to 0.64 cm. expressed as a percentage of aggregate side weight.

[c]PFZ: s. c. fat trimmed to 0.00 cm. expressed as a percentage of aggregate side weight.

[d]PLO: boxed beef yield with s. c. fat trimmed to 2.54 cm.

[e]PLQ: boxed beef yield with s. c. fat trimmed to 0.64 cm.

[f]PLZ: boxed beef yield with s. c. fat trimmed to 0.00 cm.

[g]KPH: kidney, pelvic, and heart fat expressed as a percentage of hot carcass weight.

[h]Yield Grade calculated using experts' estimation of KPH (%).

[i]Yield Grade calculated using actual KPH (%).

TABLE 11. SIMPLE CORRELATION COEFFICIENTS BETWEEN INSTRUMENT MEASUREMENTS, FAT-TRIM, AND BOXED BEEF ENDPOINTS.

	n	PFO[a]	PFQ[b]	PFZ[c]	PLO[d]	PLQ[e]	PLZ[f]
Motion fat area[g], cm^2	214	.66**	.68**	.68**	-.62**	-.67**	-.67**
Motion fat thickness[g], cm	206	.63**	.67**	.67**	-.56**	-.64**	-.64**
Motion ribeye area[g], cm^2	214	-.23**	-.23**	-.23**	.28**	.27**	.26**
Stationary fat area[g], cm^2	230	.67**	.70**	.71**	-.59**	-.66**	-.67**
Stationary fat thickness[g], cm	222	.53**	.56**	.57**	-.48**	-.54**	-.54**
Stationary ribeye area[g], cm^2	230	-.19*	-.19*	-.19*	.17	.18*	.18*
Stationary loin height[g], cm	210	-.17	-.20*	-.21*	.20*	.23**	.23**
Stationary loin width[g], cm	223	-.22**	-.22**	-.22**	.26**	.25**	.25**
ToBEC beef band[h]	227	-.07	-.08	-.08	.04	.07	.07
ToBEC cross cut chuck[h]	224	-.44**	-.44**	-.44**	.45**	.46**	.46**
ToBEC hindquarter (KP included)[hi]	227	-.52**	-.53**	-.54**	.56**	.58**	.58**
ToBEC hindquarter (KP out)[hi]	229	-.53**	-.55**	-.55**	.58**	.60**	.60**
ToBEC lean trim[h]	219	-.21*	-.19*	-.19*	.20*	.19*	.19*

*P <.01, **P <.001.
[a]PFO: s .c. fat trimmed to 2.54 cm. expressed as a percentage of aggregate side weight.
[b]PFQ: s. c. fat trimmed to 0.64 cm. expressed as a percentage of aggregate side weight.
[c]PFZ: s. c. fat trimmed to 0.00 cm. expressed as a percentage of aggregate side weight.
[d]PLO: boxed beef yield with s. c. fat trimmed to 2.54 cm.
[e]PLQ: boxed beef yield with s. c. fat trimmed to 0.64 cm.
[f]PLZ: boxed beef yield with s. c. fat trimmed to 0.00 cm.
[g]Video Image Analysis measurements obtained either online or at rest.
[h]Total Body Electrical Conductivity peak value.
[i]KP: kidney and pelvic fat.

TABLE 12. OBSERVED VARIATION (R^2) IN BOXED BEEF YIELD (% SIDE WEIGHT BASIS) AT 0.64 CM FAT-TRIM EXPLAINED BY AN INDIVIDUAL INDEPENDENT VARIABLE.

Independent variable	Code	R^2	RSD (%)
Actual Yield Grade	AYG	.8338	1.15
Experts' Yield Grade	EYG	.8194	1.19
Experts' fat thickness, cm	EFT	.7168	1.50
USDA Yield Grade[a]	USYG	.5922	1.71
VIA, motion fat area, cm^2	MFA	.4490	2.11
VIA, stationary fat area, cm^2	SFA	.4419	2.11
VIA, motion fat thickness, cm	MFT	.4088	2.18
ToBEC peak value, hindquarter KP out	THO	.3593	2.26
Experts' ribeye area, cm^2	REA	.3495	2.27
ToBEC peak value, hindquarter KP in	THI	.3349	2.31
VIA, stationary fat thickness, cm	SFT	.2942	2.36
Actual kidney/pelvic/heart fat, %	AKP	.2342	2.46
Experts' kidney/pelvic/heart fat, %	EKP	.2257	2.47
ToBEC peak value, cross-cut chuck	TCC	.2088	2.53
VIA, motion loin area, cm^2	MLA	.0719	2.74
VIA, stationary loin width, cm	SLW	.0646	2.76
VIA, stationary loin height, cm	SLH	.0536	2.85
ToBEC peak value, lean-trim	TLT	.0368	2.80
VIA, stationary loin area, cm^2	SLA	.0312	2.78
ToBEC peak value, beef band	TBB	.0043	2.83

[a]USDA Yield Grade determined by USDA graders on-line.

TABLE 13. OBSERVED VARIATION (R^2) IN BOXED BEEF YIELD (%, SIDE WEIGHT BASIS) AT 0.64 CM FAT-TRIM EXPLAINED BY COMBINATIONS OF USDA YIELD GRADE FACTORS AND INSTRUMENT MEASUREMENTS.

USDA Yield Grade factors and instrument measures	R^2	RSD (%)
EFT, THOSW[a], KPH, HCW	.8807	0.98
EFT, THO[b], KPH, HCW	.8724	1.02
EFT, REA, EKP, HCW	.8512	1.09
EFT, REA, HCW	.7966	1.27
EFT, SLA[c], KPH, HCW	.7931	1.30
EFT, MLA[d], KPH, HCW	.7919	1.31
EFT, MLA, HCW	.7284	1.49
EFT, SLA, HCW	.7242	1.49
MFT[e], REA, KPH, HCW	.7239	1.50
SFT[f], REA, KPH, HCW	.6836	1.59
MFT, MLA, KPH, HCW, MFA[g]	.6290	1.75
MFT, REA, HCW	.6286	1.74
MFT, MLA, KPH, MFA	.6255	1.75
SFA[h], SLA, KPH, HCW	.5936	1.82
MFA, MLA, KPH, HCW	.5875	1.84
SFT, SLA, KPH, HCW, SFA	.5865	1.82
SFT, REA, HCW	.5864	1.82
SFT, SLA, KPH, SFA	.5856	1.82
MFT, MLA, KPH, HCW	.5746	1.87
MFT, MLA, MFA, HCW	.5348	1.95
MFT, MLA, MFA	.5285	1.96
MFA, MLA, HCW	.4871	2.05
SFA, SLA, HCW	.4784	2.05
SFT, SLA, SFA, HCW	.4734	2.05
SFT, SLA, SFA	.4714	2.05
SFT, SLA, KPH, HCW	.4644	2.07
MFT, MLA, HCW	.4397	2.14
SFT, SLA, HCW	.3054	2.35

[a]THOSW = ToBEC peak value, hindquarter (KP out) divided by side weight.
[b]THO = ToBEC peak value, hindquarter (KP out).
[c]SLA = stationary loin area, cm^2.
[d]MLA = motion loin area, cm^2.
[e]MFT = motion fat thickness, cm.
[f]SFT = stationary fat thickness, cm.
[g]MFA = motion fat area, cm^2.
[h]SFA = stationary fat area, cm^2.

TABLE 14. REGRESSION EQUATIONS FOR PERCENTAGE BOXED BEEF (SIDE WEIGHT BASIS) AT 0.64 CM FAT-TRIM USING USDA YIELD GRADE FACTORS AND VIDEO IMAGE ANALYSIS MEASUREMENTS AS INDEPENDENT VARIABLES.

Intercept	EFT[a]	MFT[b]	SFT[c]	ERA[d]	MLA[e]	SLA[f]	AKP[g]	EKP[h]	HCW[i]	R^2	RSD
55.729	-2.907			.085			-.967		-.016	.8635	1.045
55.425	-2.882			.087				-1.197	-.016	.8512	1.091
59.479		-2.040			.018			-1.835	-.009	.5746	1.865
58.173			-1.478			.018		-1.949	-.006	.4644	2.070

[a]EFT = experts' adjusted fat thickness, cm.
[b]MFT = motion fat thickness, cm.
[c]SFT = stationary fat thickness, cm.
[d]ERA = experts' ribeye area, cm^2.
[e]MLA = motion loin area, cm^2.
[f]SLA = stationary loin area, cm^2.
[g]AKP = actual kidney/pelvic/heart/fat expressed as a percentage of side weight.
[h]EKP = experts' estimation of kidney/pelvic/heart/fat (%).
[i]HCW = hot carcass weight, kg.

TABLE 15. REGRESSION EQUATIONS FOR PERCENTAGE BOXED BEEF (SIDE WEIGHT BASIS) AT 0.64 CM FAT-TRIM USING USDA YIELD GRADE FACTORS AND TOTAL BODY ELECTRICAL CONDUCTIVITY (ToBEC) PEAK PHASE VALUES AS INDEPENDENT VARIABLES.

Intercept	EFT[a]	THI[b]	THO[c]	THISW[d]	THOSW[e]	EKP[f]	HCW[g]	R^2	RSD
60.627	-2.554	.016				-.875	-.031	.8556	1.084
60.919	-2.288		.019			-.884	-.036	.8724	1.017
54.073	-2.433			3.096		-.808	-.014	.8623	1.059
53.434	-2.138				3.624	-.816	-.017	.8807	.983

[a]EFT = experts' adjusted fat thickness, cm.
[b]THI = ToBEC peak phase for hindquarter (KP in).
[c]THO = ToBEC peak phase for hindquarter (KP out).
[d]THISW = THI divided by side weight.
[e]THOSW = THO divided by side weight.
[f]EKP = experts' estimation of kidney/pelvic/heart/fat (%).
[g]HCW = hot carcass weight, kg.

FIGURE 1. VIDEO IMAGE ANALYSIS SYSTEM.

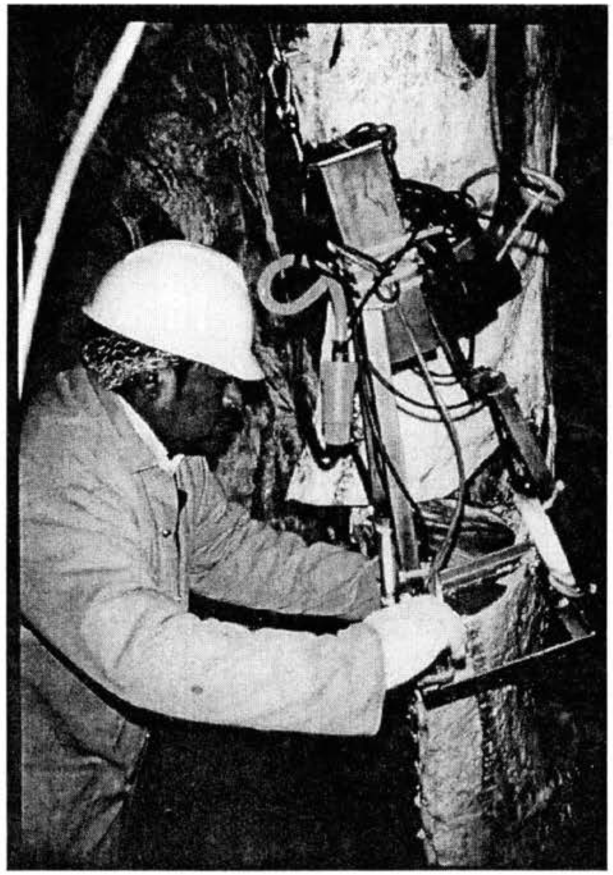

FIGURE 2. TOTAL BODY ELECTRICAL CONDUCTIVITY UNIT.

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CHAPTER IV

BEEF CARCASS VALUE DETERMINATION USING BOXED BEEF YIELD

ABSTRACT

A database was developed from fabrication data obtained from 573 carcasses (steers = 453, heifers = 120). Carcass grade data were collected and sides were fabricated into boneless subprimals following progressive hotel, restaurant, and institutional trade guidelines. Boxed beef yields for individual major subprimals (shoulder clod, chuck roll, ribeye roll, strip loin, tenderloin, top butt, inside round, gooseneck, and knuckle), minor subprimals (loose meats), 80% lean trim, and 50% lean trim were calculated at the commodity-trimmed and closely-trimmed levels and stratified by USDA Yield Grade. Yield Grade, Quality Grade, drop credit, harvest and fabrication costs, carcass weight, and dressing percentage were entered as variables into a spreadsheet program to estimate beef value when boxed beef product was fabricated at the commodity-trim or close-trim endpoints. This program facilitates precise estimation of beef value as yield, quality, and processing parameters vary.

Introduction

Approximately 80% of fed beef is fabricated as boxed beef at either commodity (maximum of 2.54 cm external fat) or close-trim (maximum of .64 cm external fat) specifications. Therefore, identification of beef value depends upon method of marketing (boxed beef vs carcass), Quality Grade (Prime, Choice, Select, Standard) and fat-trim level (commodity vs close). Lorenzen *et al.* (1993) reported that estimated excess fat production was responsible for a $219.25 loss for every steer and heifer harvested in 1991, and as a result the .64 cm fat trim level was proposed as the new "commodity" fat-trim specification for boxed beef primals and subprimals. Production of closely-trimmed subprimals has subsequently increased during the previous 3 years and has remained steady at current production levels of approximately 43% (Dolezal, 1996); however, the 1995 NBQA (NCBA, 1996) estimated that economic losses resulting from excess fat production have decreased 4.8% in comparison to the 1991 NBQA.

For production of closely-trimmed boxed beef to increase beyond present levels, a value-based method of estimating beef value to address the proper signals (premiums and discounts) must be developed. The purpose of this project was to utilize carcass grade and yield parameters in combination with harvest and fabrication costs to precisely estimate beef value.

Materials and Methods

A database was created from carcass fabrication data collected from 573 carcasses (steers = 453, heifers = 120). Carcasses were fabricated into boneless boxed beef following progressive HRI guidelines as set forth by commercial beef packers and Institutional Meat Purchase Specifications (IMPS; USDA, 1990). Major subprimals fabricated were as follows: shoulder clod (IMPS 114), chuck roll (IMPS 116A), ribeye roll (IMPS 112A), strip loin (IMPS 180), tenderloin (IMPS 189A), top butt (IMPS 184), inside round (IMPS 168), gooseneck (IMPS 170), and knuckle (IMPS 167). Minor subprimals obtained included: brisket (IMPS 120), bottom sirloin flap (IMPS 185A), bottom sirloin ball tip (IMPS 185B), bottom sirloin tri-tip (IMPS 185C), flank steak (IMPS 193), skirt meat, cap and wedge meat, and back ribs; moreover, 80% and 50% lean trim were separated. Least squares means were calculated for the main effect of Yield Grade (YG1, YG2, YG3, and YG4) for carcass grade characteristics and yields using the GLM procedure of SAS (SAS, 1986).

Carcass weight, USDA Quality and Yield grade, harvest and fabrication costs, drop credit, and estimated dressing percentage were included as independent variables in a computer spreadsheet (Figure 3). Carcass weight, Quality and Yield grade, and dressing percentage are intended to be identified by the program user. Drop credit is obtained from the USDA National Carlot Meat Report. Harvest and fabrication costs are estimated and increase as trim level progresses from commodity to close and as whole Yield Grade increases.

Multiple regression equations were developed to predict kilograms of boxed beef subprimals, lean trim, fat trim, and bone on a side weight basis at both the commodity and close fat trim level using the STEPWISE (MAXR) procedure of SAS (SAS, 1986). Carcass weight, Yield Grade, $(\text{Carcass weight})^2$, $(\text{Yield Grade})^2$, and appropriate interactions were used as independent variables. The R^2, residual standard deviation, Cp (Mallows, 1973) were considered when selecting equations. These prediction equations were entered into the spreadsheet program and used to determine subrpimal weight as carcass weight and Yield Grade varied.

Prices were applied to individual suprimals and lean trim dependent on USDA Quality Grade, external fat trim level, and product weight classification when appropriate. Estimated live weight and gross carcass, gross live, net carcass, and net live values ($/45.4 kg) could then be calculated.

Results and Discussion

Least squares means characterizing the carcasses utilized in this project stratified by USDA Yield Grade are presented in Table 16. As expected, adjusted fat thickness (AFT) increased ($P<.05$) and ribeye area (REA) decreased ($P<.05$) as Yield Grade became less desirable. Hot carcass weight (HCW), and kidney, pelvic, and heart fat percentage (KPH) increased ($P<.05$) as numerical Yield Grade increased from YG 2 to YG 3 and from YG 3 to YG 4; however, HCW and KPH did not differ ($P>.05$) from YG1 to YG2. Ranges for Yield Grade parameters (not in tabular form) are: HCW, 251.7 to 457.2 kg; REA, 60 to 121.9

cm^2; AFT, .20 to 3.25 cm. Least squares means for Yield Grades were as follows: YG1 (1.54), YG 2 (2.53), YG3 (3.45), and YG 4 (4.33). Quality Grade consist was 60.2% U.S. Choice and 39.8% U.S. Select.

A pricing matrix for boxed beef product is depicted in Table 17. The matrix presents prices for U.S. Choice and U.S. Select major subprimals, minor subprimals, 80% lean trim, and 50% lean trim at commodity- and close-trim fat levels. These prices were used to estimate beef value (live and carcass basis).

Boneless boxed beef product expressed as a percentage of cumulative side weight for commodity-trim (Table 18) and close-trim (Table 19) is stratified by USDA Yield Grade. Typically, side yield of a particular product is decreased when progressing from commodity-trim to close-trim due to more extensive removal of external fat. However, as a result of common fabrication techniques, yields appeared to be similar for ribeye roll, sirloin flap, ball tip, tenderloin, skirt meat, cap and wedge meat, 75% lean trim, and 50% lean trim. The similarities in yields for these boxed beef products are a result of fabrication guidelines because external fat is removed from these subprimals at both the commodity-trimmed and closely-trimmed fat levels.

Prediction equations for individual subprimals, lean trim, fat trim, and bone for commodity and close fat trim levels are given in Tables 20 and 21, respectively. Predictive accuracy of commodity-trim equations ranged from R^2 = .047 to .727, and for close-trim R^2 = .047 to .692.

Carcass equivalent and live animal values generated by the computer spreadsheet are categorized by Quality Grade, fat trim level, and Yield Grade (Table 22). As expected, price differentials ($/45.4 kg) between commodity-trim and close-trim boxed beef products (carcass equivalent and live basis) were substantial. However, the magnitude of the differential diminished as predicted cutability decreased (numeric Yield Grade increased) because of the additional fat removed with closely-trimmed fabrication. The absolute value difference between commodity-trimmed and closely-trimmed boxed beef wholesale prices for a U.S. Choice Yield Grade 2 carcass was $ 41.30.

Currently, most feedlots manage and market cattle on a lot basis. Therefore, uniformity is an important factor in determining an average price for a lot of cattle. To demonstrate the influence of uniformity in carcass production the live value for a lot of average harvest cattle (n = 100) where 81 carcasses conformed to industry standards and were fabricated as boxed beef and 19 were non-conformers and were marketed as carcasses was calculated as set forth by Dolezal (1996). Table 23 lists the relative values for the 81 carcasses that conformed to weight (249.5 to 430.9 kg) and grade (U.S. Prime, U.S. Choice, U.S. Select; Yield Grade 3 or better) specifications for boxed beef fabrication. A live price was determined using commodity-trimmed boxed beef predicted prices from Table 22 that corresponded with the Quality and Yield Grade consist. The value listed for U.S. Choice, Yield Grade 3 was set as the base price. The adjusted live value ($/45.4 kg) for the conformers (n=81) was $71.91.

Value adjustments for the 19 carcasses that did not conform to industry standards (weight, grade, defects) are presented in Table 24. The average discount for the 19 non-conformers is \$3.58 per 45.4 kg of carcass weight or \$2.28 per 45.4 kg of live weight (\$3.58 X 63.75% dress). The average live value for this lot of harvest cattle (n = 100) can be determined by subtracting the non-conformer discount (\$2.28/45.4 kg) from the conformer adjusted live value (\$71.91/45.4 kg). Therefore, the average live value for the entire lot would be \$69.63 per 45.4 kg of live weight.

Closely-trimmed boxed beef prices were applied to the same conformer lot consist (Table 26) utilized in the commodity based price example to demonstrate the impact of close-trimming on live value. Considering the discount for non-conformers (\$2.28/45.4 kg), the lot price for these 100 cattle would calculate to \$72.38 on a live weight basis.

Implications

The boxed beef calculation spreadsheet may be used to determine value of harvest animals on a live and carcass equivalent basis. Consideration of Quality grade, Yield grade, carcass weight, drop credit, harvest plus fabrication costs, and dressing percentage provides the flexibility to calculate values as animal characteristics and market conditions vary. This program can be utilized by producers and packers to estimate the potential value of individual animals or carcasses.

TABLE 16. LEAST SQUARES MEANS FOR CARCASS TRAITS STRATIFIED BY USDA YIELD GRADE.

	USDA Yield Grade			
	1	2	3	4
Carcass trait:				
Number of carcasses	60	190	242	81
Hot carcass weight, kg	340.12[a]	341.35[a]	348.75[b]	356.74[c]
Adjusted fat thickness, cm	0.77[a]	1.14[b]	1.52[c]	2.06[d]
Ribeye area, cm^2	100.27[a]	88.25[b]	79.39[c]	75.11[d]
Kidney, pelvic, and heart fat, %	2.04[a]	2.13[a]	2.40[b]	2.72[c]
USDA Yield Grade	1.54[a]	2.53[b]	3.45[c]	4.33[d]

[abcd]Means in the same row with a common superscript are not different (P > .05).

TABLE 17. PRICING MATRIX FOR BOXED BEEF SUBPRIMALS[a].

IMPS	Subprimal	Commodity-trim Choice	Commodity-trim Select	Close-trim Choice	Close-trim Select
112A	Ribeye < 4.99 kg	$525.00	$340.00	$525.00	$340.00
112A	Ribeye > 4.99 kg	$420.00	$340.00	$420.00	$340.00
114	Shoulder Clod	$120.00	$120.00	$134.00	$134.00
116A	Chuck Roll	$117.00	$117.00	$136.00	$132.00
120	Brisket	$109.00	$100.00	$136.00	$136.00
167	Knuckle	$145.00	$133.00	$165.00	$153.00
168	Inside Round	$140.00	$128.00	$154.00	$141.00
170	Gooseneck	$138.00	$128.00	$157.00	$150.00
180	Strip Loin < 5.44 kg	$320.00	$215.00	$421.00	$285.00
180	Strip Loin 5.44 to 6.35 kg	$320.00	$215.00	$421.00	$285.00
180	Strip Loin 6.35 kg or >	$310.00	$210.00	$421.00	$285.00
184	Top Butt < 5.44 kg	$163.00	$135.00	$187.00	$155.00
184	Top Butt > 5.44 kg	$163.00	$135.00	$187.00	$155.00
185A	Bottom Sirloin Flap	$188.00	$188.00	$188.00	$188.00
185B	Bottom Sirloin Ball Tip < .91 kg	$165.00	$160.00	$165.00	$160.00
185B	Bottom Sirloin Ball Tip > .91 kg	$170.00	$165.00	$170.00	$165.00
185C	Bottom Sirloin Tri-Tip	$160.00	$150.00	$179.00	$168.00
189A	Tenderloin < 2.27 kg	$725.00	$690.00	$725.00	$690.00
189A	Tenderloin 2.27 kg or >	$725.00	$690.00	$725.00	$690.00
193	Flank Steak	$350.00	$335.00	$350.00	$335.00
	Skirt Meat	$162.00	$162.00	$162.00	$162.00
	Cap and Wedge Meat	$185.00	$185.00	$185.00	$185.00
	Back Ribs	$57.00	$57.00	$57.00	$57.00
	80% Lean Trim	$78.00	$78.00	$78.00	$78.00
	50% Lean Trim	$57.00	$57.00	$57.00	$57.00

[a]Reflects market prices ($/45.4 kg) on October 31, 1996.

TABLE 18. LEAST SQUARES MEANS FOR KILOGRAMS COMMODITY-TRIMMED BOXED BEEF SUBPRIMALS (SIDE WEIGHT BASIS).

		USDA Yield Grade			
IMPS	Subprimal	1	2	3	4
112A	Ribeye Roll	6.35^{a}	5.93^{b}	5.69^{c}	5.66^{d}
114	Shoulder Clod	9.90	9.81	9.85	10.08
116A	Chuck Roll	14.68	14.47	14.48	14.44
120	Brisket	5.54	5.43	5.39	5.58
167	Knuckle	5.35^{a}	5.12^{ab}	4.92^{c}	5.00^{bc}
168	Inside Round	11.24^{a}	10.57^{b}	10.13^{c}	10.04^{c}
170	Gooseneck	14.18^{a}	13.26^{b}	12.83^{c}	12.72^{c}
180	Strip Loin	6.68^{ab}	6.48^{b}	6.50^{b}	6.75^{a}
184	Top Butt	6.03^{ab}	5.90^{b}	6.00^{b}	6.21^{a}
185A	Bottom Sirloin Flap	1.64	1.63	1.62	1.63
185B	Bottom Sirloin Ball Tip	1.14	1.08	1.04	0.99
185C	Bottom Sirloin Tri-Tip	1.39	1.41	1.44	1.42
189A	Tenderloin	3.02^{a}	2.79^{b}	2.64^{c}	2.58^{c}
193	Flank Steak	0.92^{a}	0.87^{b}	0.84^{bc}	0.82^{c}
	Skirt Meat	2.09^{a}	2.03^{a}	1.94^{b}	2.00^{ab}
	Cap and Wedge Meat	7.01^{a}	6.88^{a}	6.50^{c}	6.09^{d}
	Back Ribs	3.33^{a}	3.10^{b}	3.05^{b}	3.15^{b}
	80% Lean Trim	15.17	15.15	15.37	15.05
	50% Lean Trim	11.12^{a}	9.98^{b}	10.06^{b}	11.36^{a}
	Fat trim to 2.54 cm	18.82^{a}	23.42^{b}	28.16^{c}	31.51^{d}
	Bone	24.16	23.71	23.68	23.90
	Cumulative Side Weight	169.76^{ab}	169.01^{a}	172.15^{b}	177.00^{c}

[abcd]Means in the same row with a common superscript are not different (P > .05).

TABLE 19. LEAST SQUARES MEANS FOR KILOGRAMS OF CLOSELY-TRIMMED BONELESS BOXED BEEF SUBPRIMALS (SIDE WEIGHT BASIS).

		USDA Yield Grade			
IMPS	Subprimal	1	2	3	4
112A	Ribeye Roll	6.35[a]	5.93[b]	5.69[c]	5.66[c]
114	Shoulder Clod	9.41[a]	9.13[a]	8.90[b]	8.83[b]
116A	Chuck Roll	13.75[a]	13.45[a]	13.11[b]	12.51[c]
120	Brisket	4.72	4.53	4.45	4.53
167	Knuckle	5.18[a]	4.87[b]	4.65[c]	4.71[bc]
168	Inside Round	10.66[a]	9.84[b]	9.23[c]	8.93[d]
170	Gooseneck	13.88[a]	12.73[b]	12.15[c]	11.96[c]
180	Strip Loin	6.22[a]	5.73[b]	5.43[c]	5.27[c]
184	Top Butt	5.62[a]	5.34[b]	5.23[b]	5.20[b]
185A	Bottom Sirloin Flap	1.64	1.63	1.62	1.63
185B	Bottom Sirloin Ball Tip	1.14	1.08	1.04	0.99
185C	Bottom Sirloin Tri-Tip	1.33[a]	1.25[b]	1.21[c]	1.16[d]
189A	Tenderloin	3.02[a]	2.79[b]	2.64[c]	2.58[c]
193	Flank Steak	0.92[a]	0.87[b]	0.84[bc]	0.82[c]
	Skirt Meat	2.09[a]	2.03[a]	1.94[b]	2.00[ab]
	Cap and Wedge Meat	7.01[a]	6.88[a]	6.50[c]	6.09[d]
	Back Ribs	3.33	3.10	3.05	3.15
	80% Lean Trim	15.17	15.15	15.37	15.05
	50% Lean Trim	11.12[a]	9.98[b]	10.06[b]	11.36[a]
	Fat trim to 0.64 cm	22.07[a]	28.09[b]	34.10[c]	38.61[d]
	Bone	24.16	23.71	23.68	23.90
	Cumulative Side Weight	168.77[a]	168.08[a]	170.90[a]	174.95[b]

[abcd]Means in the same row with a common superscript are not different ($P > .05$).

TABLE 20. REGRESSION EQUATIONS FOR KILOGRAMS OF COMMODITY-TRIMMED BOXED BEEF SUBPRIMALS, LEAN-TRIM, FAT-TRIM AND BONE (SIDE WEIGHT BASIS).

Dependent variable	Intercept	HCW[a]	YG[b]	C2[c]	Y2[d]	YC[e]	YC2[f]	Y2C[g]	Y2C2[h]	R^2	RSD
Ribeye Roll, 2x2	6.4262	-.0193	-.3300	.00007	.0930		-.000005			.495	0.55
Shoulder Clod	5.9009		-.3508	.00004					.0000003	.694	0.60
Chuck Roll	6.7312			.00007	-.0683					.697	0.99
Brisket	1.4683	.0138	-.4734					.0002		.348	0.68
Knuckle	3.3405			.00003		-.0024		.0003		.354	0.63
Inside Round	3.9115	.0260	-1.1037					.0002		.655	0.69
Gooseneck	7.6728			.00007	.1489	-.0048				.727	0.75
Strip Loin, 3x2	3.2150			.00004			-.000005	.0002		.432	0.60
Top Butt	.9519	.0164	-.4343		.0696					.536	0.48
Bottom Sirloin Flap	-.1595	.0050			-.0236	.0003				.504	0.18
Bottom Sirloin Ball Tip	-2.3909	.0178		-.00002					-.0000001	.047	0.38
Bottom Sirloin Tri-Tip	1.3178		-.8787		.1408	.0028		-.0004		.253	0.21
Tenderloin	2.6291	-.0033	-.2886	.00002	.0412		-.000001			.464	0.26
Flank Steak	1.2921	-.0047	-.0916	.00001				.00008	-.0000002	.473	0.10
Skirt Meat	1.3951		-.2116	.000008	.0233					.276	0.30
Cap and Wedge Meat	-14.3793	.1068		-.0001	-.0776					.283	1.07
Back Ribs	8.3477	-.0381		.00007			-.000005	.0002		.169	0.47
80% Lean Trim	1.0054	.0395			-.1693	.0021				.575	1.21
50% Lean Trim	31.2662	-.1541		.0003	.6406	-.0112				.190	2.50
Fat trim to 2.54 cm	-56.8212	.3451	3.8096	-.0004			.00003	-.0014		.614	3.75
Bone	16.4089		-.9668	.00008					.0000007	.439	2.10

[a]HCW=hot carcass weight (kg), [b]YG=USDA Yield Grade, [c]$C2=HCW^2$, [d]$Y2=YG^2$, [e]YC=YG x HCW, [f]$YC2=YG \times HCW^2$, [g]Y2C=YG x HCW, [h]$Y2C2=YG \times HCW^2$.

TABLE 21. REGRESSION EQUATIONS FOR KILOGRAMS OF CLOSELY-TRIMMED BOXED BEEF SUBPRIMALS, LEAN-TRIM, FAT-TRIM AND BONE (SIDE WEIGHT BASIS).

Dependent variable	Intercept	HCW[a]	YG[b]	C2[c]	Y2[d]	YC[e]	YC2[f]	Y2C[g]	Y2C2[h]	R^2	RSD
Ribeye Roll, 2x2	6.4262	-.0193	-.3300	.00007	.0930		-.000005			.495	0.55
Shoulder Clod	1.4197	.0252	-.3726							.625	0.61
Chuck Roll	1.1384	.0368	-.9045			.0038			-.000002	.454	1.31
Brisket	-11.7389	.0871	-.3667	-.00001	.7550			-.0045	.000007	.347	0.67
Knuckle	-.0067		4.0733	.00005	-.5870	-.0143		.0020		.382	0.59
Inside Round	3.6774	.0257	-1.2635		.0831					.668	0.66
Gooseneck	1.8857	.0430			.5825	-.0130	.00002	-.0011		.692	0.83
Strip Loin, 3x2	0.5664	.0192	-.6611		.4605			-.0018	.000002	.439	0.55
Top Butt	3.6030		-.5074	.00002				.0004	-.0000007	.550	0.43
Bottom Sirloin Flap	-.1595	.0050			-.0236	.0003				.504	0.18
Bottom Sirloin Ball Tip	-2.3909	.0178		-.00002					-.0000001	.047	0.38
Bottom Sirloin Tri-Tip	-.0767	.0044					-.000006			.283	0.16
Tenderloin	2.6291	-.0033	-.2886	.00002	.0412		-.000001			.464	0.26
Flank Steak	1.2921	-.0047	-.0916	.00001				.00008	-.0000002	.473	0.10
Skirt Meat	1.3951		-.2116	.000008	.0233					.276	0.30
Cap and Wedge Meat	-14.3793	.1068		-.0001	-.0776					.283	1.07
Back Ribs	8.3477	-.0381		.00007			-.000005	.0002		.169	0.47
80% Lean Trim	1.0054	.0395			-.1693	.0021				.575	1.21
50% Lean Trim	31.2662	-.1541		.0003	.6406	-.0112				.190	2.50
Fat trim to 0.64 cm	-67.7618	.4166	4.3585	-.0006			.00004	-.0016		.650	4.38
Bone	16.4089		-.9668	.00008					.0000007	.439	2.10

[a]HCW=hot carcass weight (kg), [b]YG=USDA Yield Grade, [c]C2=HCW^2, [d]Y2=YG^2, [e]YC=YG x HCW, [f]YC2=YG x HCW^2, [g]Y2C=YG x HCW, [h]Y2C2=YG x HCW^2.

TABLE 22. VALUE ($/45.4 KG) DETERMINATIONS FROM COMMODITY- AND CLOSELY-TRIMMED BOXED BEEF STRATIFIED BY QUALITY AND YIELD GRADES[a].

Yield	Commodity-trimmmed		Closely-trimmmed	
Grade	Choice	Select	Choice	Select
Carcass equivalent:				
1	$127.89	$116.45	$135.24	$122.78
2	$119.15	$108.46	$124.66	$113.22
3	$112.64	$102.43	$116.07	$105.43
4	$108.35	$98.36	$109.47	$99.41
Live basis:				
1	$81.53	$74.24	$86.21	$78.27
2	$75.96	$69.15	$79.47	$72.18
3	$71.81	$65.30	$73.99	$67.21
4	$69.07	$62.70	$69.79	$63.38

[a]Reflects market prices on October 31, 1996.

TABLE 23. LIVE VALUE ($/45.4 KG) DETERMINATION FROM COMMODITY-TRIMMED BOXED BEEF ON A LOT BASIS[a].

Grade Consist	Relative Value	Lot Adjustment
U.S. Prime (n=1; YG 3)	$15.37	0.15
U.S. Choice (n=40)		
3 % YG 1	$9.72	0.29
18 % YG 2	$4.15	0.75
19 % YG 3	Base	$71.81
U.S. Select (n=40)		
8 % YG 1	$2.43	0.19
21 % YG 2	($2.66)	(0.56)
11 % YG 3	($6.51)	(0.72)
Adjusted Live Value/45.4 kg		$71.91

[a]Reflects market prices on October 31, 1996.

TABLE 24. VALUE ($/45.4 KG) ADJUSTMENTS FOR NON-CONFORMING CARCASSES[a].

Grade Consist	Relative Value	Lot Adjustment
8% Yield Grade 4 or 5	($ 15.00)	($ 1.20)
3% Extremes in weight	($ 17.50)	($ 0.53)
3% Dark Cutters	($ 35.00)	($ 1.05)
5% U.S. Standard	($ 16.00)	($ 0.80)
Carcass Discount/cwt.		($ 3.58)
Adjustment to Lot Live Value/cwt (assuming 63.75% dress)		($ 2.28)

[a]Reflects market prices on October 31, 1996.

TABLE 25. LIVE VALUE ($/45.4 KG) DETERMINATION FROM CLOSELY-TRIMMED BOXED BEEF ON A LOT BASIS[a].

Grade Consist	Relative Value	Lot Adjustment
U.S. Prime (n=1; YG 3)	$10.46	0.10
U.S. Choice (n=40)		
3 % YG 1	$12.22	0.37
18 % YG 2	$5.48	0.99
19 % YG 3	Base	$73.99
U.S. Select (n=40)		
8 % YG 1	$4.28	0.34
21 % YG 2	($1.81)	(0.38)
11 % YG 3	($6.78)	(0.75)
Adjusted Live Value/45.4 kg		$74.66

[a]Reflects market prices on October 31, 1996.

FIGURE 3. OKLAHOMA STATE UNIVERSITY BOXED BEEF CALCULATOR OUTPUT.

OKLAHOMA STATE UNIVERSITY BOX YIELD CALCULATOR 1996 VERSION II.

	INPUTS	TRIM LEVEL	COMMOD.	0.25 INCH
CARCASS WEIGHT LBS	750	CALC ULATED LIVE WT	1176	1176
QUALITY GRADE(1=CH,2=SEL)	1	GROSS CARC VALUE	$826.90	$860.62
YIELD GRADE (1.0 TO 4.9)	3	EST DROP CREDIT	$111.88	$111.88
DROP CREDIT $ / CWT	$9.51	GROSS LIVE VALUE	$938.78	$972.51
ESTIMATED DRESS %	63.75	NET CARCASS $/CWT	$112.64	$116.07
KILL-FAB COST EST. COMOD.	$94.00	NET LIVE $/CWT	$71.81	$73.99
KILL-FAB COST EST. .25 INCH	$102.00	US CHOICE		CLOSE PREM.
		YIELD GRADE 3		$25.73

THESE DATA WERE UPDATEI 10/31/96	RECOVERY-%	97.96	97.53

THE USER MUST SUPPLY THE BOXED BEEF CUTOUT VALUES IN THE BOX BELOW:

BOXED BEEF CUTS	COMMODITY TRIM		CLOSE (0.25")TRIM		COMMODITY	0.25 INCH
(GRADE--->>)	CHOICE	SELECT	CHOICE	SELECT	POUNDS	POUNDS
112A RIBEYE <11 lbs	$525.00	$340.00	$525.00	$340.00	24.95	24.95
112A RIBEYE 11> lbs	$420.00	$340.00	$420.00	$340.00		
114 SH CLOD	$120.00	$120.00	$134.00	$134.00	42.51	39.18
116A CHUCK ROLL	$117.00	$117.00	$136.00	$132.00	62.62	58.14
120 BRISKET	$109.00	$100.00	$136.00	$136.00	23.39	19.51
167 KNUCKLE	$145.00	$133.00	$165.00	$153.00	21.52	20.38
168 INSIDE RND	$140.00	$128.00	$154.00	$141.00	44.88	41.33
170 GOOSENECK	$138.00	$128.00	$157.00	$150.00	56.30	53.63
180 STRIP LOIN <12 lbs	$320.00	$215.00	$421.00	$285.00	28.14	24.35
180 STRIP LOIN 12-13.9 #	$320.00	$215.00	$421.00	$285.00		
180 STRIP LOIN 14> lbs	$310.00	$210.00	$421.00	$285.00		
184 TOP BUTT <12 lbs	$163.00	$135.00	$187.00	$155.00	25.78	22.81
184 TOP BUTT 12> lbs	$163.00	$135.00	$187.00	$155.00		
185A BOT SRLN FLAP	$188.00	$188.00	$188.00	$188.00	7.10	7.10
185B BOT SRLN BALL TIP <2	$165.00	$160.00	$165.00	$160.00	4.74	4.74
185B BOT SRLN BALL TIP 2>	$170.00	$165.00	$170.00	$165.00		
185C BOT SRLN TRITIP	$160.00	$150.00	$179.00	$168.00	6.20	5.39
189A TENDERLOIN <5 lbs	$725.00	$690.00	$725.00	$690.00	11.71	11.71
189A TENDERLOIN 5> lbs	$725.00	$690.00	$725.00	$690.00		
193 FLANK STEAK	$350.00	$335.00	$350.00	$335.00	3.63	3.63
INSIDE SKIRT	$162.00	$162.00	$162.00	$162.00	8.55	8.55
CAP & WEDGE MEAT	$185.00	$185.00	$185.00	$185.00	24.60	24.60
BACK RIBS	$57.00	$57.00	$57.00	$57.00	13.13	13.13
80% LEAN TRIM	$78.00	$78.00	$78.00	$78.00	66.46	66.46
50% LEAN TRIM	$57.00	$57.00	$57.00	$57.00	41.67	41.67
			EDIBLE TALLOW---->>		114.11	137.48
			BONE------------------->>		102.72	102.72
			TOTAL #		734.71	731.47

IMPORTANT NOTICE: THE DATA USED IN MAKING THESE ESTIMATES WERE OBTAINED FROM CUTTING TESTS IN A COMMERCIAL PACKING PLANT. 453 STEERS AND 120 HEIFERS WERE CUT. THE CARCASSES WEIGHED 555-1008 POUNDS. FAT THICKNESS RANGED FROM 0.08-1.28 INCHES. RIBEYE AREA RANGED FROM 9.3-18.9 sq.in. THE TEST CARCASSES GRADED 60.2% CHOICE AND 39.8% SELECT.

SUGGESTED USE RANGE IS 650-875 POUND CARCASSES AND YIELD GRADES BETWEEN 1.0 AND 4.5.

DEVELOPED AT OKLAHOMA STATE UNIVERSITY BY GLEN DOLEZAL, DONALD GILL AND TOM GARDNER

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APPENDIX

TABLE 26. SIMPLE CORRELATION COEFFICIENTS BETWEEN CARCASS TRAITS, YIELD GRADE, LEAN-TRIM, AND BONE.

	n	P81[a]	P8Q[b]	P8Z[c]	P51[d]	P50[e]	PBO[f]
USDA Yield Grade	224	-.40**	-.39**	-.47**	.31**	.32**	-.40**
Adjusted fat thickness, cm	240	-.43**	-.42**	-.50**	.31**	.34**	-.61**
Ribeye area, cm^2	240	.23**	.23**	.29**	-.13	-.14	-.04
Estimated KPH, (%)[b]	240	-.43**	-.43**	-.44**	.19*	.20*	-.29**
Actual KPH, (%)[b]	240	-.49**	-.49**	-.49**	.07	.10	-.34**
Hot carcass weight	240	-.08	-.08	-.10	.12	.10	-.15
Experts' Yield Grade	240	-.45**	-.44**	-.53**	.30**	.32**	-.39**
Actual Yield Grade	240	-.47**	-.46**	-.54**	.29**	.31**	-.40**

**P <.01, **P <.001.

[a]P81: 80% lean-trim (s. c. fat trimmed to 2.54 cm) expressed as a percentage of aggregate side weight.

[b]P8Q: 80% lean-trim (s. c. fat trimmed to 0.64 cm) expressed as a percentage of aggregate side weight.

[c]P8Z: 80% lean-trim (s. c. fat trimmed to 0.00 cm) expressed as a percentage of aggregate side weight.

[d]P51: 50% lean-trim (s. c. fat trimmed to 2.54 cm) expressed as a percentage of aggregate side weight.

[e]P50: 50% lean-trim (s. c. fat trimmed to ≤ 0.64 cm) expressed as a percentage of aggregate side weight.

[f]PBO: bone expressed as a percentage of aggregate side weight.

[g]KPH: kidney, pelvic, and heart fat expressed as a percentage of hot carcass weight.

[h]Yield Grade calculated using experts' estimation of KPH (%).

[i]Yield Grade calculated using actual KPH (%).

TABLE 27. SIMPLE CORRELATION COEFFICIENTS BETWEEN INSTRUMENT MEASUREMENTS, LEAN-TRIM, AND BONE.

	n	P81[a]	P8Q[b]	P8Z[c]	P51[d]	P50[e]	PBO[f]
Motion fat area[g], cm^2	214	-.38**	-.37**	-.40**	.19**	.22**	-.44**
Motion fat thickness[g], cm	206	-.37**	-.36**	-.42**	.19**	.20**	-.46**
Motion ribeye area[g], cm^2	214	.15*	.14*	.17*	-.05	.07	-.04
Stationary fat area[g], cm^2	230	-.35**	-.34**	-.40**	.38**	.40**	-.59**
Stationary fat thickness[g], cm	222	-.30**	-.29**	-.34**	.25**	.27**	-.42**
Stationary ribeye area[g], cm^2	230	.08	.07	.07	.08	.06	.11
Stationary loin height[g], cm	210	-.01	-.02	.02	-.03	-.04	.10
Stationary loin width[g], cm	223	.09	.09	.13	-.03	-.007	.04
ToBEC beef band[h]	227	.05	.05	.04	.11	.09	.02
ToBEC cross cut chuck[h]	224	.30**	.30**	.33**	.006	-.04	.16
ToBEC hindquarter (KP included)[hi]	227	.34**	.33**	.36**	-.14	-.18*	.20*
ToBEC hindquarter (KP out)[hi]	229	.33**	.32**	.36**	-.16	-.19*	.19*
ToBEC lean trim[h]	219	.16	.16	.16	-.06	-.10	.11

*P <.01, **P <.001.

[a]P81: 80% lean-trim (s.c. fat trimmed to 2.54 cm) expressed as a percentage of aggregate side weight.

[b]P8Q: 80% lean-trim (s. c. fat trimmed to 0.64 cm) expressed as a percentage of aggregate side weight.

[c]P8Z: 80% lean-trim (s. c. fat trimmed to 0.00 cm) expressed as a percentage of aggregate side weight.

[d]P51: 50% lean-trim (s. c. fat trimmed to 2.54 cm) expressed as a percentage of aggregate side weight.

[e]P50: 50% lean-trim (s. c. fat trimmed to $\leq$ 0.64 cm) expressed as a percentage of aggregate side weight.

[f]PBO: bone expressed as a percentage of aggregate side weight.

[g]Video Image Analysis measurements obtained either online or at rest.

[h]Total Body Electrical Conductivity peak value.

[i]KP: kidney and pelvic fat.

TABLE 28. SIMPLE CORRELATION COEFFICIENTS BETWEEN FAT-TRIM, LEAN-TRIM, AND BOXED BEEF ENDPOINTS.

	n	PFO[a]	PFQ[b]	PFZ[c]	PLO[d]	PLQ[e]	PLZ[f]
Bone (%)	240	-.68**	-.68**	-.67**	.37**	.46**	.47**
s. c. fat trim (2.54 cm)	240	-------	.99**	.99**	-.91**	-.93**	-.93**
s. c. fat-trim (0.64 cm)	240	.99**	-------	.99**	-.90**	-.95**	-.95**
s. c. fat-trim (0.00 cm)	240	.99**	.99**	-------	-.90**	-.95**	-.95**
Boxed beef yield (2.54 cm fat-trim)	240	-.91**	-.90**	-.90**	-------	.98**	.97**
Boxed beef yield (0.64 cm fat-trim)	240	-.93**	-.95**	-.95**	.98**	-------	.99**
Boxed beef yield (0.00 cm fat-trim)	240	-.93**	-.95**	-.95**	.97**	.99**	-------
80% lean-trim (2.54 cm fat-trim)	240	-.63**	-.61**	-.61**	.55**	.55**	.55**
80% lean-trim (0.64 cm fat-trim)	240	-.62**	-.60**	-.60**	.54**	.54**	.54**
80% lean-trim (0.00 cm fat-trim)	240	-.68**	-.66**	-.66**	.62**	.63**	.62**
50% lean-trim (2.54 cm fat-trim)	240	.29**	.29**	.30**	-.38**	-.37**	-.36**
50% lean-trim (≤ 0.64 cm fat-trim)	240	.33**	.33**	.33**	-.39**	-.39**	-.39**

*P <.01, **P <.001.

[a]PFO: s. c. fat trimmed to 2.54 cm. expressed as a percentage of aggregate side weight.
[b]PFQ: s. c. fat trimmed to 0.64 cm. expressed as a percentage of aggregate side weight.
[c]PFZ: s. c. fat trimmed to 0.00 cm. expressed as a percentage of aggregate side weight.
[d]PLO: boxed beef yield with s. c. fat trimmed to 2.54 cm.
[e]PLQ: boxed beef yield with s. c. fat trimmed to 0.64 cm.
[f]PLZ: boxed beef yield with s. c. fat trimmed to 0.00 cm.

TABLE 29. SIMPLE CORRELATION COEFFICIENTS BETWEEN BONE, FAT-TRIM, BOXED BEEF ENDPOINTS AND LEAN-TRIM.

	n	P81[a]	P8Q[b]	P8Z[c]	P51[d]	P50[e]	PBO[f]
Bone (%)	240	.24**	.23**	.24**	-.31**	-.36**	-------
s. c. fat trim (2.54 cm)	240	-.63**	-.62**	-.68**	.29**	.33**	-.68**
s. c. fat-trim (0.64 cm)	240	-.61**	-.60**	-.66**	.29**	.33**	-.68**
s. c. fat-trim (0.00 cm)	240	-.61**	-.60**	-.66**	.30**	.33**	-.67**
Boxed beef yield (2.54 cm fat-trim)	240	.55**	.54**	.62**	-.38**	-.39**	.37**
Boxed beef yield (0.64 cm fat-trim)	240	.55**	.54**	.63**	-.37**	-.39**	.46**
Boxed beef yield (0.00 cm fat-trim)	240	.55**	.54**	.62**	-.36**	-.39**	.47**
80% lean-trim (2.54 cm fat-trim)	240	-------	.99**	.96**	-.27**	-.29**	.24**
80% lean-trim (0.64 cm fat-trim)	240	.99**	-------	.96**	-.28**	-.30**	.23**
80% lean-trim (0.00 cm fat-trim)	240	.96**	.96**	-------	-.31**	-.33**	.24**
50% lean-trim (2.54 cm fat-trim)	240	-.27**	-.28**	-.31**	-------	.97**	-.31**
50% lean-trim ($\leq$ 0.64 cm fat-trim)	240	-.29**	-.30**	-.33**	.97**	-------	-.36**

[a]P81: 80% lean-trim (s. c. fat trimmed to 2.54 cm) expressed as a percentage of aggregate side weight.
[b]P8Q: 80% lean-trim (s. c. fat trimmed to 0.64 cm) expressed as a percentage of aggregate side weight.
[c]P8Z: 80% lean-trim (s. c. fat trimmed to 0.00 cm) expressed as a percentage of aggregate side weight.
[d]P51: 50% lean-trim (s. c. fat trimmed to 2.54 cm) expressed as a percentage of aggregate side weight.
[e]P50: 50% lean-trim (s. c. fat trimmed to $\leq$ 0.64 cm) expressed as a percentage of aggregate side weight.
[f]PBO: bone expressed as a percentage of aggregate side weight.

TABLE 30. OBSERVED VARIATION (R^2) IN BOXED BEEF YIELD (% SIDE WEIGHT BASIS) AT 2.54 CM FAT-TRIM EXPLAINED BY AN INDIVIDUAL INDEPENDENT VARIABLE.

Independent variable	Code	R^2	RSD (%)
Actual Yield Grade	AYG	.7650	1.02
Experts' Yield Grade	EYG	.7404	1.07
Experts' fat thickness, cm	EFT	.5739	1.37
USDA Yield Grade[a]	USYG	.4906	1.44
VIA, motion fat area, cm^2	MFA	.3801	1.67
VIA, stationary fat area, cm^2	SFA	.3509	1.70
Experts' ribeye area, cm^2	REA	.3502	1.70
ToBEC peak value, hindquarter KP out	THO	.3393	1.72
VIA, motion fat thickness, cm	MFT	.3178	1.74
ToBEC peak value, hindquarter KP in	THI	.3107	1.76
Actual kidney/pelvic/heart fat, %	AKP	.3075	1.75
Experts' kidney/pelvic/heart fat, %	EKP	.2720	1.80
VIA, stationary fat thickness, cm	SFT	.2279	1.85
ToBEC peak value, cross-cut chuck	TCC	.2025	1.90
VIA, motion loin area, cm^2	MLA	.0785	2.04
VIA, stationary loin width, cm	SLW	.0693	2.06
ToBEC peak value, lean-trim	TLT	.0403	2.08
VIA, stationary loin height, cm	SLH	.0394	2.14
VIA, stationary loin area, cm^2	SLA	.0275	2.09
ToBEC peak value, beef band	TBB	.0018	2.12

[a]USDA Yield Grade determined by USDA graders on-line.

TABLE 31. OBSERVED VARIATION (R^2) IN BOXED BEEF YIELD (% SIDE WEIGHT BASIS) AT 0.00 CM FAT-TRIM EXPLAINED BY AN INDIVIDUAL INDEPENDENT VARIABLE.

Independent variable	Code	R^2	RSD (%)
Actual Yield Grade	AYG	.8309	1.19
Experts' Yield Grade	EYG	.8174	1.24
Experts' fat thickness, cm	EFT	.7168	1.54
USDA Yield Grade[a]	USYG	.5900	1.77
VIA, motion fat area, cm^2	MFA	.4515	2.18
VIA, stationary fat area, cm^2	SFA	.4468	2.17
VIA, motion fat thickness, cm	MFT	.4047	2.26
ToBEC peak value, hindquarter KP out	THO	.3639	2.33
Experts' ribeye area, cm^2	REA	.3525	2.33
ToBEC peak value, hindquarter KP in	THI	.3388	2.38
VIA, stationary fat thickness, cm	SFT	.2967	2.44
Actual kidney/pelvic/heart fat, %	AKP	.2192	2.56
Experts' kidney/pelvic/heart fat, %	EKP	.2103	2.58
ToBEC peak value, cross-cut chuck	TCC	.2077	2.61
VIA, motion loin area, cm^2	MLA	.0693	2.84
VIA, stationary loin width, cm	SLW	.0624	2.86
VIA, stationary loin height, cm	SLH	.0550	2.94
ToBEC peak value, lean-trim	TLT	.0344	2.89
VIA, stationary loin area, cm^2	SLA	.0334	2.87
ToBEC peak value, beef band	TBB	.0050	2.92

[a]USDA Yield Grade determined by USDA graders on-line.

TABLE 32. OBSERVED VARIATION (R^2) IN BOXED BEEF YIELD (%) AT 2.54 CM FAT-TRIM EXPLAINED BY COMBINATIONS OF USDA YIELD GRADE FACTORS AND INSTRUMENT MEASUREMENTS.

USDA Yield Grade factors and instrument measures	R^2	RSD (%)
EFT, THOSW[a], KPH, HCW	.8164	0.91
EFT, THO[b], KPH, HCW	.8045	0.94
EFT, REA, EKP, HCW	.7861	0.98
MFT[c], REA, KPH, HCW	.7171	1.13
EFT, MLA[d], KPH, HCW	.6998	1.17
EFT, REA, HCW	.6947	1.17
EFT, SLA[e], KPH, HCW	.6934	1.18
SFT[f], REA, KPH, HCW	.6892	1.18
MFT, MLA, KPH, HCW, MFA[g]	.5972	1.35
MFT, MLA, KPH, MFA	.5938	1.36
EFT, MLA, HCW	.5915	1.36
MFT, REA, HCW	.5823	1.37
EFT, SLA, HCW	.5781	1.38
MFA, MLA, KPH, HCW	.5723	1.40
SFT, REA, HCW	.5545	1.41
SFA[h], SLA, KPH, HCW	.5488	1.43
MFT, MLA, KPH, HCW	.5430	1.44
SFT, SLA, KPH, HCW, SFA	.5375	1.44
SFT, SLA, KPH, SFA	.5366	1.44
MFT, MLA, MFA, HCW	.4610	1.56
MFT, MLA, MFA	.4541	1.57
SFT, SLA, KPH, HCW	.4498	1.57
MFA, MLA, HCW	.4266	1.61
SFA, SLA, HCW	.3835	1.67
SFT, SLA, SFA, HCW	.3737	1.67
SFT, SLA, SFA	.3714	1.67
MFT, MLA, HCW	.3575	1.70
SFT, SLA, HCW	.2389	1.84

[a]THOSW = ToBEC peak value, hindquarter (KP out) divided by side weight.
[b]THO = ToBEC peak value, hindquarter (KP out).
[c]MFT = motion fat thickness, cm.
[d]MLA = motion loin area, cm^2.
[e]SLA = stationary loin area, cm^2.
[f]SFT = stationary fat thickness, cm.
[g]MFA = motion fat area, cm^2.
[h]SFA = stationary fat area, cm^2.

TABLE 33. OBSERVED VARIATION (R^2) IN BOXED BEEF YIELD (%) AT 0.00 CM FAT-TRIM EXPLAINED BY COMBINATIONS OF USDA YIELD GRADE FACTORS AND INSTRUMENT MEASUREMENTS.

USDA Yield Grade factors and instrument measures	R^2	RSD (%)
EFT, THOSW[a], KPH, HCW	.8804	1.02
EFT, THO[b], KPH, HCW	.8716	1.05
EFT, REA, EKP, HCW	.8444	1.15
EFT, REA, HCW	.7975	1.31
EFT, SLA[c], KPH, HCW	.7851	1.36
EFT, MLA[d], KPH, HCW	.7831	1.38
EFT, MLA, HCW	.7288	1.54
EFT, SLA, HCW	.7250	1.54
MFT[e], REA, KPH, HCW	.7136	1.58
SFT[f], REA, KPH, HCW	.6773	1.66
MFT, REA, HCW	.6302	1.79
MFT, MLA, KPH, HCW, MFA[g]	.6135	1.84
MFT, MLA, KPH, MFA	.6102	1.85
SFT, REA, HCW	.5915	1.86
SFA[h], SLA, KPH, HCW	.5890	1.88
SFT, SLA, KPH, HCW, SFA	.5802	1.90
SFT, SLA, KPH, SFA	.5789	1.89
MFA, MLA, KPH, HCW	.5759	1.93
MFT, MLA, KPH, HCW	.5556	1.97
MFT, MLA, MFA, HCW	.5310	2.03
MFT, MLA, MFA	.5251	2.03
MFA, MLA, HCW	.4874	2.12
SFA, SLA, HCW	.4859	2.10
SFT, SLA, SFA, HCW	.4793	2.11
SFT, SLA, SFA	.4769	2.11
SFT, SLA, KPH, HCW	.4545	2.16
MFT, MLA, HCW	.4340	2.22
SFT, SLA, HCW	.3096	2.42

[a]THOSW = ToBEC peak value, hindquarter (KP out) divided by side weight.
[b]THO = ToBEC peak value, hindquarter (KP out).
[c]SLA = stationary loin area, cm^2.
[d]MLA = motion loin area, cm^2.
[e]MFT = motion fat thickness, cm.
[f]SFT = stationary fat thickness, cm.
[g]MFA = motion fat area, cm^2.
[h]SFA = stationary fat area, cm^2.

TABLE 34. REGRESSION EQUATIONS FOR PERCENTAGE BOXED BEEF (SIDE WEIGHT BASIS) AT 2.54 CM FAT-TRIM USING USDA YIELD GRADE FACTORS AND VIDEO IMAGE ANALYSIS MEASUREMENTS AS INDEPENDENT VARIABLES.

Intercept	EFT[a]	MFT[b]	SFT[c]	ERA[d]	MLA[e]	SLA[f]	AKP[g]	EKP[h]	HCW[i]	R^2	RSD
57.522	-1.611			.078			-.975		-.015	.8160	.909
57.126	-1.596			.080				-1.160	-.015	.7861	.980
60.511		-1.262			.015			-1.602	-.006	.5430	1.438
59.617			-.919			.014		-1.679	-.004	.4498	1.570

[a]EFT = experts' adjusted fat thickness, cm.
[b]MFT = motion fat thickness, cm.
[c]SFT = stationary fat thickness, cm.
[d]ERA = experts' ribeye area, cm^2.
[e]MLA = motion loin area, cm^2.
[f]SLA = stationary loin area, cm^2.
[g]AKP = actual kidney/pelvic/heart/fat expressed as a percentage of side weight.
[h]EKP = experts' estimation of kidney/pelvic/heart/fat (%).
[i]HCW = hot carcass weight, kg.

TABLE 35. REGRESSION EQUATIONS FOR PERCENTAGE BOXED BEEF (SIDE WEIGHT BASIS) AT 0.00 CM FAT-TRIM USING USDA YIELD GRADE FACTORS AND VIDEO IMAGE ANALYSIS MEASUREMENTS AS INDEPENDENT VARIABLES.

Intercept	EFT[a]	MFT[b]	SFT[c]	ERA[d]	MLA[e]	SLA[f]	AKP[g]	EKP[h]	HCW[i]	R^2	RSD
52.204	-3.008			.089			-.934		-.017	.8562	1.106
51.888	-2.986			.091				-1.144	-.017	.8444	1.151
56.183		-2.115			.018			-1.804	-.009	.5556	1.973
54.877			-1.539			.019		-1.920	-.007	.4545	2.157

[a]EFT = experts' adjusted fat thickness, cm.
[b]MFT = motion fat thickness, cm.
[c]SFT = stationary fat thickness, cm.
[d]ERA = experts' ribeye area, cm^2.
[e]MLA = motion loin area, cm^2.
[f]SLA = stationary loin area, cm^2.
[g]AKP = actual kidney/pelvic/heart/fat expressed as a percentage of side weight.
[h]EKP = experts' estimation of kidney/pelvic/heart/fat (%).
[i]HCW = hot carcass weight, kg.

TABLE 36. REGRESSION EQUATIONS FOR PERCENTAGE BOXED BEEF (SIDE WEIGHT BASIS) AT 2.54 CM FAT-TRIM USING USDA YIELD GRADE FACTORS AND TOTAL BODY ELECTRICAL CONDUCTIVITY (ToBEC) PEAK PHASE VALUES AS INDEPENDENT VARIABLES.

Intercept	EFT[a]	THI[b]	THO[c]	THISW[d]	THOSW[e]	EKP[f]	HCW[g]	R^2	RSD
61.746	-1.393	.014				-.901	-.026	.7742	1.015
62.006	-1.149		.016			-.907	-.031	.8045	.941
56.233	-1.286			2.607		-.843	-.013	.7834	.994
55.582	-1.015				3.114	-.847	-.015	.8164	.912

[a]EFT = experts' adjusted fat thickness, cm.
[b]THI = ToBEC peak phase for hindquarter (KP in).
[c]THO = ToBEC peak phase for hindquarter (KP out).
[d]THISW = THI divided by side weight.
[e]THOSW = THO divided by side weight.
[f]EKP = experts' estimation of kidney/pelvic/heart/fat (%).
[g]HCW = hot carcass weight, kg.

TABLE 37. REGRESSION EQUATIONS FOR PERCENTAGE BOXED BEEF (SIDE WEIGHT BASIS) AT 0.00 CM FAT-TRIM USING USDA YIELD GRADE FACTORS AND TOTAL BODY ELECTRICAL CONDUCTIVITY (ToBEC) PEAK PHASE VALUES AS INDEPENDENT VARIABLES.

Intercept	EFT[a]	THI[b]	THO[c]	THISW[d]	THOSW[e]	EKP[f]	HCW[g]	R^2	RSD
57.430	-2.614	.018				-.801	-.033	.8541	1.125
57.736	-2.334		.020			-.815	-.038	.8716	1.053
50.415	-2.484			3.314		-.729	-.016	.8613	1.097
49.751	-2.174				3.866	-.743	-.018	.8804	1.097

[a]EFT = experts' adjusted fat thickness, cm.
[b]THI = ToBEC peak phase for hindquarter (KP in).
[c]THO = ToBEC peak phase for hindquarter (KP out).
[d]THISW = THI divided by side weight.
[e]THOSW = THO divided by side weight.
[f]EKP = experts' estimation of kidney/pelvic/heart/fat (%).
[g]HCW = hot carcass weight, kg.

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VITA

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Doctor of Philosophy

Thesis: INSTRUMENT ASSESSMENT OF BEEF CARCASS CUTABILITY AND ESTIMATION OF BOXED BEEF VALUE

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