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

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Story in Brief

Beef carcasses (n = 240) were selected from typical daily production in a commercial beef conversion facility to fill a 2 x 6 x 2 matrix of sex-class (steer vs heifer), experts' Yield grade (EYG: 1, 2A, 2B, 3A, 3B, 4), and weight-class (light = 550 to 749 lb; heavy = 750 to 950 lb). Grade data were collected from stationary carcasses by an expert committee to determine experts' Yield Grade. Video Image Analysis (VIA) was used to evaluate left sides at the 12th rib interface. Variables were obtained in motion (M) or at rest (S) for subcutaneous fat thickness (MFT or SFT) and ribeye area (MLA or SLA). Modified beef sides were placed in a ToBEC chamber to obtain peak phase values: H1PEAK, hindquarter + kidney and pelvic fat and H2PEAK, hindquarter - kidney and pelvic fat. Sides were fabricated following progressive HRI guidelines. Subjective and objective measurements were used as independent variables in multiple regression equations developed to predict side percentage of boneless, closely-trimmed boxed beef. Experts' estimation of Yield Grade factors + hot carcass weight accounted for 85% of the variation in closely-trimmed boxed beef. Substitution of VIA ribeye measurements (MLA or SLA) for experts' measurements reduced equation accuracy by approximately 6%. Equations substituting ToBEC peak value for experts' estimation of muscling were similar in accuracy to equations using experts' measurements. The results of this study indicate that Yield Grade accurately predicts boneless, closely-trimmed boxed beef yield and objective measurements of individual Yield Grade factors can be used to enhance the accuracy of on-line Yield Grade application.

(Key Words: Beef, Cutability, Equation, Image, Meat, Prediction.)

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 function 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 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 cutabiltiy. Wassenberg et al. (1986) evaluated the ability of VIA variables to predict red meat yield of steer carcasses: total primal lean weight (R^2 = .96) and percent primal lean (R^2 = .46). Moreover, Gwartney et al. (1994) indicated that ToBEC scanning could account for 75 or 80% of the variation in percentage lean of steer and heifer sides, respectively.

The objective of this study was to determine, in a commercial beef conversion complex, the accuracy of VIA, ToBEC and Yield Grade in predicting boneless, closely-trimmed boxed beef percentage of steer and heifer sides varying in weight-class and Yield Grade.

Materials and Methods

Approximately 48 h postmortem, beef carcasses wee presented at chain speeds of 350 to 400 carcasses per hour as a portion of daily plant production and assigned Quality and Yield Grades by a USDA grader. Immediately following grade assignments, carcasses were evaluated by a Video Image Analysis (VIA) system operated by plant personnel. The following VIA motion variables were obtained at the 12th rib interface at normal chain speed: subcutaneous fat thickness (MFT) and ribeye area (MLA).

Following evaluation by USDA graders and motion VIA, 240 beef carcasses (steers n = 120, heifers n = 120) were selected by university 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 vs heifer), experts' Yield Grade (EYG: 1, 2A, 2B, 3A, 3B, 4), and weight-class (light = 550 to 749 lb; heavy = 750 to 950 lb). Selected carcasses were placed on a stationary rail where university and USDA carcass evaluation experts independently assessed carcass grade characteristics without time constraint and using measuring aids. The averages of the three experts' measurements of adjusted fat thickness (AFT) and ribeye area (REA) were recorded with hot carcass weight (HCW) as actual carcass measurements. Actual kidney/pelvic/heart fat percentage (AKPH) was calculated using actual internal fat weights obtained in subsequent side fabrication. The expert committee evaluated kidney/pelvic/heart fat percentage (KPH) subjectively. Actual Yield Grade was calculated using experts' measurements of AFT and REA as well as HCW and AKPH. Experts' Yield Grade was determined substituting KPH for AKPH. Although USDA Quality Grade factors were evaluated, they were not considered in the carcass selection process. The expert committee examined each carcass for workmanship defects that might influence red meat yield before finalizing selection.

Following selection, left sides of carcasses were evaluated by VIA (stationary) and ToBEC. Stationary VIA measurement of subcutaneous fat thickness (SFT) and ribeye area (SLA) were obtained at the 12th rib interface. Prior to fabrication, left sides were quartered and modified for ToBEC scanning. 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).

A team of beef fabrication trainers processed each side following grade data collection and instrument evaluations. Trainers processed boneless, closely-trimmed (1/4" residual s. c. fat) subprimals following progressive HRI specifications as set forth by the packer. Weights of the various lean products, fat trim and bone were recorded individually for each side processed.

As 2 x 6 x 2 matrix of sex-class, experts' Yield Grade, and weight-class was utilized. The main effects of sex-class, experts' Yield Grade, and weight-class as well as appropriate interactions were tested for significance (P<.05) using the GLM procedure of SAS (1986). Least squares means for carcass characteristics and cutability endpoints were determined using the GLM procedure of SAS (1986). Actual carcass, VIA and ToBEC measurements were used as independent variables in the STEPWISE procedure of SAS (1986) to generate multiple regression equations predicting side percentage of boneless, closely-trimmed boxed beef.

Results and Discussion

Least squares means are reported for the main effects of experts' Yield Grade, sex-class, and weight-class as tests of main effect interactions were not significant (P>.05), with the expectation of an experts' Yield Grade x weight-class interaction for percentage of bone (P<.05). Main effect means are reported for percentage of bone but care must be taken to account for the statistically significant interaction.

Carcass grade characteristic least squares means stratified by experts' Yield Grade, sex-class, and weight-class are presented in Table 1. Hot carcass weight did not differ between experts' Yield grade groups; however , steer and heavy carcasses were heavier (P<.05) than heifer and light carcasses.

Marbling scores were highest (P<.05) for EYG 3A, 3B, and 4 and when coupled with youthful maturity qualified these carcasses for the U. S. Choice quality grade. Heifer carcasses had higher (P<.05) marbling scores than steers placing heifers in the U. S. Choice Quality Grade. Although marbling scores were in the "small" category for heavy and light carcasses, heavys had higher (P<.05) scores then lights.

As expected, fat thickness and adjusted fat thickness increased (P<.05) with each numerical increase in experts' Yield Grade. More specifically, adjusted fat thickness increased (P<.05) within EYG 2 and 3. Steer and light carcasses had lower (P<.05) actual and adjusted fat thickness values than heifers and heavys, respectively.

Ribeye area was largest (P<.05) for EYG 1 and decreased (P<.05) with each increase in experts' Yield Grade category. Differences were noted for sex-class and weight-class with steers and lights having smaller (P<.05) ribeyes than heifer and heavy carcasses, respectively.

When categorized by experts' Yield Grade, internal fat percentage (actual and estimated) was greatest (P<.05) for EYG 3B and 4. Steer carcasses possessed less (P<.05) actual and estimated kidney, pelvic and heart fat than heifer carcasses. Carcasses in the light category had a lower (P<.05) percentage of estimated internal fat than heavy carcasses; however, actual internal fat percentage did not differ (P>.05).

By design, experts□ and actual Yield Grade means increased (P<.05) with each increasing category. Experts□ Yield Grade did not differ (P>.05) for sex-class or weight-class. Actual Yield Grade was higher (P<.05) for heifer vs steer carcasses but did not differ (P>.05) for weight-class.

Cutability endpoints stratified by experts□ Yield Grade, sex-class, and weight-class are presented in Table 2. As expected, boxed beef yield decreased (P<.05) and fat trim yield increased (P<.05) as experts□ Yield Grade increased numerically. Boxed beef yields ranged from 54% for EYG 1 to 46.7% for EYG 4. Steer and light carcasses yielded more (P<.05) boxed beef and less (P<.05) ¼" s. c. fat trim than heifers and heavys, respectively. Side yield of 80% lean trim was greatest (P<.05) for EYG 1, steers, and lights. Fifty percent lean trim did no differ (P>.05) for sex-class but yields were lowest (P<.05) for EYG 1, 2A, 2B and light sides. Caution must be used when comparing bone yield differences because of the experts□ Yield Grade x weight-class interaction.

Equations using USDA Yield Grade factors and VIA measurements to estimate side percentage of boxed beef are presented in Table 3. The most accurate equation (R^2 = .86; RSD = 1.05) included experts□ adjusted fat thickness and ribeye area as well as hot carcass weight and actual internal fat percentage. Substitution of experts□ estimation of KPH for AKPH reduced accuracy by 1.3%. These results indicate that properly measured USDA Yield Grade factors successfully estimate boneless, closely-trimmed boxed beef. However, USDA Yield Grade applied to these carcasses on-line accounted for only 59% of the variation in closely-trimmed boxed beef. Equations that included AFT, KPH, HCW, and VIA measurement of ribeye area (motion or stationary) accounted for 79% of the variation in the cutability endpoint. Removal of KPH from the previous equations reduced accuracy by 6 to 7 %. VIA measurements of fat thickness (MFT or SFT) and ribeye area (MLA or SLA) combined with KPH and HCW produced equations with reduced accuracy (MFT/MLA, R^2 = .57; SFT/SLA, R^2 = .46).

Total Body Electrical Conductivity measures of muscling were used in combination with USDA Yield Grade factors to develop prediction equations (Table 4). Accuracy of ToBEC equations that used hindquarter (kidney and pelvic fat in) peak phase coupled with AFT, KPH, and HCW were similar in accuracy to equations using experts□ measurements of Yield Grade factors. Substitution of hindquarter (kidney and pelvic fat removed) peak phase increased equation accuracy by 1 to 2.5 %.

Implications

This study indicates that USDA Yield Grades are successful in predicting boxed beef (1/4" s. c. fat trim) yield when factors are accurately assessed and properly applied; however, at normal chain speeds USDA graders have only 7 to 20 seconds to assess Yield and Quality Grades and apply their stamp. Subsequently, accuracy of on-line Yield Grade application is reduced. Objective measurements of Yield Grade factors can improve predictive accuracy. Although equations using ToBEC variables were most accurate, ToBEC assessment is costly and cannot be completed in the normal product flow. However, VIA variables can be used in conjunction with subjective estimates to enhance the accuracy of equations predicting boneless, closely-trimmed boxed beef yield.

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Table1. Carcass grade characteristics stratified by experts□ Yield Grade[a], sex-class, and weight-class.

		Grade characteristic[b]								
Group		HCW	MARB	FT	AFT	REA	EKP	AKP	EYG	A
Experts□ Yield Grade										
	1	747.2	376.0[c]	.26[c]	.31[c]	15.7[c]	2.1[c]	2.7[c]	1.5[c]	1
	2A	752.0	393.8[c]	.35[d]	.41[d]	14.2[d]	2.2[cd]	2.8[c]	2.2[d]	2
	2B	740.5	394.4[c]	.39[d]	.50[e]	13.5[e]	2.3[d]	3.1[de]	2.7[e]	2
	3A	745.1	429.6[d]	.56[e]	.63[f]	12.9[f]	2.3[d]	2.9[cd]	3.2[f]	3
	3B	755.4	433.9[d]	.60[e]	.69[g]	12.2[g]	2.7[e]	3.4[e]	3.7[g]	3
	4	748.8	457.7[d]	.85[f]	.91[h]	11.4[h]	2.6[e]	3.4[e]	4.4[h]	4
Sex-class										
	Steer	757.4[d]	394.2[c]	.46[c]	.53[c]	13.1[c]	2.3[c]	2.8[c]	2.9[c]	3
	Heifer	738.9[c]	434.2[d]	.55[d]	.62[d]	13.5[d]	2.5[d]	3.3[d]	3.0[c]	3
Weight-class										

	Light (<750 lb)	689.2[c]	401.1[c]	.49[c]	.56[c]	12.5[c]	2.3[c]	3.0[c]	2.9[c]	3
	Heavy (≥ 750 lb)	807.1[d]	427.3[d]	.52[d]	.59[d]	14.2[d]	2.5[d]	3.1[c]	3.0[c]	3

[a] Experts□ Yield Grade was computed using experts□ adjusted fat thickness, experts□ ribeye area, experts□ estimated internal fat percentage, and actual hot carcass weight.

[b] CWT=hot carcass weight, lb; MARB=marbling score (300 to 399 corresponds to "Slight" degree of marbling; 400 to 499 corresponds to "Small" degree of marbling); FT=fat thickness, in.; AFT=adjusted fat thickness, in.; REA=ribeye area, in.^{2}; EKP=experts□ estimated internal fat, %; AKP=actual internal fat, %; EYG=experts□ yield grade; AYG=actual yield grade calculated substituting AKP for EKP.

[c,d,e,f,g,h] Means in the same column and group with a common superscript letter are not different (P>.05).

Table 2. Carcass cutability endpoints (1/4" fat trim) stratified by experts□ Yield Grade[a], sex-class, and weight-class.

		Cutability endpoint				
Group		Boxed Beef	Fat Trim	80% Lean Trim	50% Lean Trim	Bone
Experts□ Yield Grade						
	1	54.03[b]	13.02[b]	11.57[b]	6.98[b]	14.39[b]
	2A	52.37[c]	14.99[c]	11.23[c]	6.96[b]	14.45[b]
	2B	51.22[d]	16.41[d]	11.28[c]	6.96[b]	14.12[bc]
	3A	49.60[e]	18.27[e]	11.20[c]	7.23[c]	13.69[cd]
	3B	48.62[f]	19.61[f]	10.94[d]	7.34[cd]	13.48[de]
	4	46.68[g]	22.01[g]	10.75[d]	7.49[d]	13.08[e]

Sex-class						
	Steer	50.83[b]	16.27[b]	11.28[d]	7.17	14.45[d]
	Heifer	50.02[c]	18.50[c]	11.05[c]	7.15	13.29[c]
Weight-class						
	Light (<750 lbs	50.64[b]	16.93[b]	11.24[d]	7.09[b]	14.10[d]
	Heavy (≥ 750 lb)	50.21[c]	17.84[c]	11.09[c]	7.23[c]	13.64[c]

[a] Experts’ Yield Grade was computed using experts’ adjusted fat thickness, experts’ ribeye area, experts’ estimated internal fat percentage, and actual hot carcass weight.

[b,c,d,e,f,g] Means in the same column and group with a common superscript letter are not different (P>.05).

Table 3. Prediction of boxed beef yield at ¼ inch s.c. fat trim using USDA Yield Grade factors and Video Image Analysis (VIA) measurements as independent variables.

USDA Yield Grade factors and VIA measures	R2	RSD (%)
Experts’ adjusted fat thickness, in		
Experts’ ribeye area, in^2		
Actual kidney/pelvic/heart fat, %		
Hot carcass weight, lb	.8635	1.05
Experts’ adjusted fat thickness, in		
Experts’ ribeye area, in^2		
Experts’ estimation of kidney/pelvic/heart fat, %		
Hot carcass weight, lb	.8512	1.09
Experts’ adjusted fat thickness, in		

VIA, stationary loin area, in^2		
Experts□ estimation of kidney/pelvic/heart fat, %		
Hot carcass weight, lb	.7931	1.30
Experts□ adjusted fat thickness, in		
VIA, motion loin area, in^2		
Experts□ estimation of kidney/pelvic/heart fat, %		
Hot carcass weight, lb	.7919	1.31
Experts□ adjusted fat thickness, in		
VIA, motion loin area, in^2		
Hot carcass weight, lb	.7284	1.49
Experts□ adjusted fat thickness, in		
VIA, stationary loin area, in^2		
Hot carcass weight, lb	.7242	1.49
VIA, motion fat thickness, in		
VIA, motion loin area, in^2		
Experts□ estimation of kidney/pelvic/heart fat, %		
Hot carcass weight, lb	.5746	1.87
VIA, stationary fat thickness, in		
VIA, stationary loin area, in^2		
Experts□ estimation of kidney/pelvic/heart fat, %		
Hot carcass weight, lb	.4644	2.07

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Table 4. Prediction of boxed beef yield at ¼ inch s.c. fat trim using USDA Yield Grade factors and Total Body Electrical Conductivity (ToBEC) measurements as independent variables.		
USDA Yield Grade factors and ToBEC measures	R2	RSD (%)
Experts□ adjusted fat thickness, in		
Hindquarter peak phase, kidney/pelvic fat out		
divided by side weight, lb		
Experts□ estimation of kidney/pelvic/heart fat, %		
Hot carcass weight, lb	.8807	.98
Experts□ adjusted fat thickness, in		
Hindquarter peak phase, kidney/pelvic fat out		
Experts□ estimation of kidney/pelvic/heart fat, %		
Hot carcass weight, lb	.8724	1.02
Experts□ adjusted fat thickness, in		
Hindquarter peak phase, kidney/pelvic fat in		
divided by side weight, lb		
Experts□ estimation of kidney/pelvic/heart fat, %		
Hot carcass weight, lb	.8623	1.06
Experts□ adjusted fat thickness, in		

Hindquarter peak phase, kidney/pelvic fat in Experts□ estimation of kidney/pelvic/heart fat, % Hot carcass weight, lb	.8556	1.08

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