APPLICATION OF ELECTROMAGNETIC SCANNING FOR PREDICTION OF BEEF CARCASS COMPOSITION

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SUMMARY

Forty beef cattle were used to evaluate the application of electromagnetic scanning for prediction of beef carcass composition. Left carcass sides were used for quality and yield grade evaluation. Right sides were quartered between the 12th and 13th ribs and scanned with EM-SCAN HA-2 and MQ-25 electromagnetic scanners to measure total body electrical conductivity (TOBEC). Warm carcass weight, TOBEC index (phase curve peak), length and temperature of quarters were used to develop prediction equations for lean mass in beef sides which were compared to equations based on yield grade factors. Results suggest that electrical conductivity is useful in estimating lean weight in beef carcasses. The MQ-25 instrument has potential value for precise estimates of carcass composition.

INTRODUCTION

Total body electrical conductivity is a rapid, non-invasive method to detect lean content in animal carcasses. The principle is based on the greater electrical conductivity in lean tissue than in fat because of greater water and electrolyte content. Studies conducted at Purdue University using TOBEC instruments have shown a high correlation between TOBEC indexes and lean content in pork carcasses (FORREST et al., 1989). In this experiment, a hospital model HA-2 (EM-SCAN Inc., Springfield, Illinois) for human adults and an industrial model MQ-25 (Meat Quality Inc., Springfield, Illinois) for pork carcasses were used to determine the TOBEC index of beef quarters. Prediction equations using TOBEC indexes were developed for estimating lean weight in beef carcass sides.

MATERIALS AND METHODS

Animal slaughter and data collection: Forty U.S.D.A. low choice or high select grade beef cattle (33 steers and 7 heifers) were slaughtered in the Purdue University Meat Science Laboratory. Slaughter weight and warm carcass weight were recorded. Right carcass sides were quartered into fore- and hindquarters between the 12th and 13th ribs. Left carcass sides were weighed and measured to determine U.S.D.A. quality and yield grades following an 18 hour chill. Fat thickness was determined over 3/4 the length on the longitudinal axis of the transverse section of the exposed longissimus muscle at the 12th rib. Percent kidney, pelvic and heart (KPH) fat, marbling (10= abundant to 1= devoid), maturity (15= A- youngest to 1= E+ oldest) and quality (17= prime to 0= utility) were estimated independently by three meat scientists. Carcass yield grades were calculated using the official U.S.D.A. yield grading formula.

Electromagnetic scanning: Two TOBEC instruments were used. A 2.5 MHz electromagnetic field created by the HA-2 is inside a cylindrical plexiglass chamber of 79 cm diameter and 185 cm length. The chamber of MQ-25 is 66 cm in diameter and 218 cm in length. Temperature and length of beef quarters were measured just before scanning. The foreshank was removed from the forequarter and placed on top of the forequarter near its original location. Thirty-four warm forequarters and hindquarters, and 35 chilled forequarters and hindquarters were scanned by the HA-2. Twenty-seven warm hindquarters and 34 chilled hindquarters were scanned by the MQ-25.

Dissection and lean standardization: Beef quarters were separated into primal cuts after scanning. Each primal cut was dissected into lean, fat (subcutaneous and intermuscular fat) and bone. Dissected lean from each cut was ground through a 0.5 cm plate three times, and then 0.5 kg of ground lean was randomly sampled and stored at -20°C for chemical analyses. Each ground lean sample was thawed at room temperature and chopped along with any purged liquid and homogenized by a commercial high speed chopper (Robot Coupe USA, Inc., Ridgeland, MS.). Triplicate 2 to 3 g chopped samples were used to determine moisture (forced air oven drying at 105°C) and lipid (Soxhlet ether extraction) content of dissected lean (AOAC., 1987). Results of lipid analyses were adjusted for the connective tissue and moisture content of the fat tissue before being used to standardize lean content. The lean standardization procedure was similar to the calculation of fat free muscle presented by FAHEY et al. (1977). Since U.S.D.A. prime, choice or select grade beef contains 70% lipid in fatty composite (SLOVER et al., 1987), fat trim was assumed to be 70% lipid and 30% water and connective tissue. The sum of lipid content in dissected lean from each primal cut was divided by 0.7 to get the inseparable fat weight of the carcass side. The total fat free lean of the beef side was determined by total dissected side lean minus the calculated inseparable fat tissue content.

Statistical analysis: Data were analyzed using simple correlation procedures and general linear model routines within the Statistical Analysis System (SAS/STAT, 1988). Based on warm carcass weight, scanned carcasses were divided into three weight groups. The weight groups were less than 295 kg (group 1), 295 kg to 342 kg (group 2), and greater than 342 kg (group 3). Scanned carcasses were sorted according to the total beef side carcass fat percentage into three different fat level groups; less than 30 % fat (group 1), 30 to 35 % fat (group 2) and greater than 35 % fat (group 3). Least squares means of residuals were used to estimate overall biases for different carcass weight groups or different fat levels.

RESULTS AND DISCUSSION

Means and standard deviations of carcass characteristics, composition and quality scores are shown in Table 1. Warm carcass weights ranged from 237 to 473 kg with an average 61.5 dressing percentage, 1.8 % cooler shrinkage, 2.5 yield grade, 0.8 cm fat thickness, 2.5 % estimated KPH fat, 81.1 cm^2 longissimus muscle area, 11.8 quality grade, A^{10} maturity and $Small^{10}$ marbling score. Average beef carcass

Table 1. Means from measured carcass parameters and carcass composition

Measured parameter	N	Mean	SD[a]
Carcass measurements:			
Slaughter wt, kg	40	532.3	71.5
Warm carcass wt, kg	40	328.1	53.5
Fat depth, 12th rib, 3/4 measurement, cm	40	0.8	0.4
Longissimus muscle area, 12th rib, cm^2	40	81.1	11.7
Kidney, pelvic and heart (KPH) fat, %	40	2.5	0.6
Marbling score[b]	40	5.1	0.8
Maturity score[c]	40	14.9	0.4
Quality grade[d]	40	11.8	1.1
Yield grade[e]	40	2.5	0.6
Dissected lean wt, kg (%)[f]	35	86.4 (56.1)	10.4 (3.2)
Dissected bone wt, kg (%)	35	24.6 (16.1)	2.9 (1.7)
Dissected fat wt, kg (%)	35	42.1 (27.1)	10.1 (4.4)
Fat free lean wt, kg (%)[g]	35	78.0 (50.7)	9.8 (3.8)
Chemical composition:			
Chemical lipid, %	35	6.9	1.4
Inseparable fat, %	35	9.8	2.0
Moisture, %	35	72.1	1.2

[a] Standard deviation.
[b] 1= Devoid, 10= abundant.
[c] 1= E+ (the oldest end), 15= A- (the youngest end).
[d] 0= Utility, 17= prime.
[e] USDA yield grade= 2.50+ (2.50x adjusted fat thickness, in.)+ (0.20x % KPH fat)+ (0.0038x hot carcass wt, lb.) - (0.32x longissimus muscle area, $in.^2$).
[f] Five forequarters did not be dissected.
[g] Fat free lean= dissected lean - (% inseparable fat x dissected lean); Inseparable fat= chemical lipid / 0.7.

lean percentage went from 56.1 % on a dissected lean basis to 50.7 % after adjustment to a fat free lean basis. These results are similar to 57.5 % separable lean and 52.7 % fat free lean reported by PARRETT et al. (1985). Fat free lean to bone ratio was 3.2, slightly less than 3.6 as reported by KAUFFMAN et al. (1975). Among the yield grade factors, warm carcass weight and longissimus muscle area were highly correlated with dissected and fat free lean weight (Table 2). The low correlation between dissected lean weight and both fat depth (.126) and KPH fat percentage (.016) is in contrast to the high correlations presented by CROSS et al. (1973) and ABRAHAM et al. (1980). TOBEC indexes of beef quarters were closely related to dissected and fat free lean weight in beef sides (r>.87; p<.001). A high correlation was observed between dissected lean weight and fat free lean weight (r=.985; p<.001). Fat free lean and dissected lean weight had similar correlations to all carcass measurements (Table 2).

Warm carcass weight was the most important factor in lean prediction equations using yield grade factors which is in agreement with work reported by MILLER et al. (1988). Warm carcass weight accounted for 81 % of the variation in dissected lean and 69 % in fat free lean. These results confirm the study by JOHNSON et al. (1989), in which carcass weight was found to be an important variable for predicting beef forequarter separable lean weight (R^2=.655). All four yield grade factors together improved the R^2 value to .916 and .869 for dissected and fat free lean, respectively, in beef sides (Table 3).

TOBEC index (phase curve peak) of scanned beef quarters were highly correlated with lean content in beef sides (r=.820 to .959; p<.001). Beef quarter length showed a medium strong correlation with beef lean content (r=.66 to .77; p<.001). Because geometry and temperature of scanned subject are important factors that influence measurements taken with the electromagnetic scanner (KLISH et al., 1984; FIOROTTO et al., 1987), warm carcass weight, conductivity index (TOBEC phase peak reading), length and temperature of the quarters were included in the prediction equations to account for these factors. In warm forequarters, fat free lean weight in beef sides was best estimated using HA-2 TOBEC index (THF) and length (HFL) of warm forequarter. Dissected lean weight was best estimated using warm carcass weight (HCW) and THF. The addition of other variables only slightly improved the R^2 values. Temperature was only significant in equations derived from chilled forequarter scanning in HA-2 and it only improved the R^2 values slightly (about 3%). The HA-2 TOBEC indexes of warm (THH) or chilled (TCH) beef hindquarters contributed significantly to multiple regression equations for predicting fat free and dissected lean weight of beef sides. The THH (or TCH) alone accounted for over 87 % of the variation in estimated fat free lean weight and over 84 % of the variation in estimated dissected lean weight. The THH (or TCH), when combined with hindquarter length, increased the R^2 values to >.90 in predicting fat free lean weight and to .93 when combined with both warm carcass weight and hindquarter length for predicting dissected lean weight. Lean prediction equations developed from the beef hindquarter had consistently higher R^2 values than those

Table 2. Simple correlation coefficients relating various carcass measurements to carcass lean content

Measured parameter	N	Dissected lean wt	Fat free lean wt
Slaughter wt	35	.862***	.792***
Warm carcass wt	35	.901***	.834***
Fat depth, 12th rib, 3/4 measurement	35	.126	.021
Longissimus muscle area, 12th rib	35	.830***	.814***
Kidney, pelvic and heart fat %	35	.061	.008
Marbling score	35	-.223	-.327
Quality grade	35	-.265	-.365*
Yield grade	35	-.161	-.258
Dissected lean wt	35	1.000	.985***
Dissected bone wt	35	.772***	.753***
Dissected fat wt	35	.432**	.320
Fat free lean wt	35	.985***	1.000
TOBEC index[a]			
HA-2 index of warm forequarters (THF)	34	.887***	.870***
HA-2 index of chilled forequarters (TCF)	35	.899***	.883***
HA-2 index of warm hindquarters (THH)	34	.928***	.934***
HA-2 index of chilled hindquarters (TCH)	35	.921***	.937***
MQ-25 index of warm hindquarters (MHH)	27	.924***	.929***
MQ-25 index of chilled hindquarters (MCH)	33	.946***	.959***
Quarter length			
Warm forequarter	34	.774***	.739***
Chilled forequarter	35	.740***	.692***
Warm hindquarter	34	.706***	.685***
Chilled hindquarter	35	.710***	.657***
Quarter temperature			
Warm forequarter	34	.266	.275
Chilled forequarter	35	.416*	.363*
Warm hindquarter	34	.230	.242
Chilled hindquarter	35	.283	.257

[a] phase curve peak reading.

* $p < .05$; ** $p < .01$; *** $p < .001$.

Table 3. Regression equations for predicting dissected and fat free lean weight (kg) in beef sides using yield grade factors or TOBEC index[a] and length of beef quarters.

Technology	Dependent variables	Equations	Independent variables	Intercept	b values	R^2	RSD
Yield grade factors	Dissected lean	1.	Warm carcass wt. (kg)	9.82*	.22***	.916	3.23
			+ 12th rib fat thickness (cm)		-6.17***		
			+ Longissimus muscle area (cm^2)		.21*		
			+ KPH fat (%)		-2.31*		
	Fat free lean	2.	Warm carcass wt. (kg)	11.15	.20***	.869	3.79
			+ 12th rib fat thickness (cm)		-8.09***		
			+ Longissimus muscle area (cm^2)		.22*		
			+ KPH fat (%)		-2.93*		
HA-2 TOBEC	Dissected lean	3.	Warm carcass wt. (kg)	25.81**	.14***	.855	4.08
			+ HA-2 index of warm forequarter[a]		.02**		
		4.	Warm carcass wt. (kg)	-2.00	.08**	.932	2.84
			+ HA-2 index of warm hindquarter[a]		.04***		
			+ Warm hindquarter length (cm)		.24*		
		5.	Warm carcass wt. (kg)	-3.62	.09**	.932	2.85
			+ HA-2 index of chilled hindquarter[a]		.07***		
			+ Chilled hindquarter length (cm)		.23*		
	Fat free lean	6.	HA-2 index of warm forequarter[a]	10.19	.03***	.792	4.61
			+ Warm forequarter length (cm)		.42*		
		7.	HA-2 index of warm hindquarter[a]	-3.29	.05***	.907	3.09
			+ Warm hindquarter length (cm)		.31**		
		8.	HA-2 index of chilled hindquarter[a]	-3.20	.10***	.908	3.08
			+ Chilled hindquarter length (cm)		.29**		
MQ-25 TOBEC	Dissected lean	9.	Warm carcass wt. (kg)	24.17***	.11***	.918	3.12
			+ MQ-25 index of warm hindquarter[a]		.07***		
		10.	Warm carcass wt. (kg)	-2.22	.06*	.950	2.42
			+ MQ-25 index of chilled hindquarter[a]		.16***		
			+ Chilled hindquarter length (cm)		.26*		
	Fat free lean	11.	MQ-25 index of warm hindquarter[a]	37.82***	.11***	.863	3.73
		12.	MQ-25 index of chilled hindquarter[a]	6.26	.20***	.933	2.56
			+ Chilled hindquarter length (cm)		.22*		

[a] phase curve peak reading.

* $p < .05$; ** $p < .01$; *** $p < .001$.

equations developed from the forequarter. This difference was most likely due to the shape of the forequarters as compared to hindquarters. When subjects are scanned by the HA-2, a minimum 5 cm clearance between their surface and the plexiglass chamber wall is needed for accurate measurements. However, it was difficult to maintain this distance when scanning forequarters from beef cattle of larger frame sizes. It is much easier to maintain minimum clearance when scanning hindquarters using current instrument configuration.

MQ-25 TOBEC indexes of beef warm (MHH) or chilled (MCH) hindquarters were the best single estimators of dissected and fat free lean weight (R^2= .86 and .92 for fat free lean and R^2= .85 and .89 for dissected lean, respectively). Based on warm hindquarter scanning, the best equation to estimate dissected lean weight was the equation including HCW and MHH (R^2=.92). In chilled hindquarters, fat free lean weight of beef sides was best estimated by using MCH and length (CHL) of chilled hindquarter (R^2=.93). The best equation to predict dissected lean weight was the equation consisting of HCW, MCH and CHL (R^2=.95). Equations that included MHH had slightly lower R^2 values than equations that included MCH. The MQ-25 TOBEC indexes were highly correlated (r=.98; p<.001) with HA-2 TOBEC indexes.

Carcass weight bias was examined by least squares means of residuals in lean prediction equations using MQ-25 TOBEC indexes (Equations 5, 6, 11 and 12). Biases due to different carcass weight groups were not significant in carcass lean prediction equations (p>.57). Carcass weight bias also had no effect on MQ-25 TOBEC indexes (p>.16). However, biases of lean estimation caused by different fat percentages in beef carcasses were observed in the equation using MQ-25 TOBEC indexes and length of chilled hindquarters (p=.08). The carcass fat free lean content was over-estimated in the high fat percentage beef carcasses (over 35 %) by Equation 12. Possibly a large amount of fat may contribute partial conductivity to the whole conductivity index, since electrical conductivity of lean tissue is about twenty-fold greater than that of fat tissue.

CONCLUSION

Lean prediction equations developed by scanning beef hindquarters were better than using forequarters, and chilled hindquarter scanning was superior to warm hindquarter scanning. Equations using the TOBEC index (determined by the MQ-25) accounted for a similar or even more of the variation than equations using the yield grade factors. The MQ-25 is a potential, powerful, and non-invasive detector of lean in beef carcasses. If the diameter of the scan chamber could be expanded to scan the entire beef side or even the whole beef carcass, the potential for practical application would be enhanced greatly.

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