S4P04.WP

ELECTROMAGNETIC SCANNING OF WARM PRE-RIGOR PORK CARCASSES IN AN ON-LINE INDUSTRIAL CONFIGURATION

E.P. BERG, J.C. FORREST and J.E. FISHER

Department of Animal Sciences, Purdue University, West Lafayette, IN 47907, United States

Please refer to Folio 25.

INTRODUCTION

Objective instrument grading is necessary for establishment of a value-based marketing system for livestock in the United States. The grading system must meet several criteria before being accepted by the United States Department of Agriculture or commercial packing plants:
(1) utilize an objective method to determine value;
(2) be implemented at time of slaughter;
(3) be applicable to "on the rail" trading; and
(4) allow for adoption in innovative slaughter and (or) processing technology (Savell and Cross, 1991).

A summary by Jones (1991) identified Ultrasound, Total Body Electrical Conductivity (TOBEC), Video Image Analysis (VIA) and Optical Grading Probes (GP) as methods with potential for commercial testing in the near future. Optical grading probes have gained wide spread acceptance in the United States and other counties as an estimate of total carcass lean or percentage carcass lean. Real-time ultrasound imaging devices have been developed which have potential for adaptation by the meat and livestock industry. Video image analysis has been studied as a means of objectively determining both yield and quality grade from computerized analysis. Forrest *et al.* (1989) published a review of potential new methods of on-line pork carcass evaluation reporting most carcass evaluation systems available to the packing industry are often subjective and fail to account for the variability in composition from carcass to carcass.

Electromagnetic scanning measures total body electrical conductivity (TOBEC) of carcasses in relation to weight or percentage of lean tissue. Since this is an appraisal obtained from measurement of the entire carcass, it provides a more accurate estimation of carcass lean across genetic type, stage of maturity and feeding regime. Estimations of carcass lean tissue derived from single points of measure (i.e., optical grading probes, VIA and ultrasound) cannot account for the varied distribution of lean tissue across carcasses. Electromagnetic scanning technology has the capacity to accurately scan 1000 carcasses per hour. The purpose of this study was to investigate industrial application of electromagnetic scanning in an on-line commercial setting.

MATERIALS AND METHODS

Carcass selection

Fifty warm, pre-rigor pork carcasses, average weight 82.2kg (±7.4kg) were selected from the daily slaughter population. Carcasses were selected from visual appraisal of last-rib back fat depth and hot carcass weight. Selection occurred over a four week period to obtain carcasses that included a wide variety of production systems. The objective of the selection was to obtain a cross-section of all types of hogs marketed at Sioux-Preme Packing Co. (Sioux Center, IA). An accurate measure of last rib backfat was obtained at the time of carcass dissection via a ruler. Loin eye tracings were obtained at the $3^{rd}/4^{th}$ from last rib interface. Loin eye area was measured by planimeter.

Electromagnetic scanning

An MQ-25 electromagnetic (EM) scanner (Meat Quality Inc., Springfield, IL) was installed on-line at Sioux-Preme Packing Co. Sioux Center, IA. The EM scanner was integrated into the existing slaughter production line prior to the chill cooler. Carcass weights were obtained, automatically sent to a computer and held on a time delay to be coupled with the EM scan data from each specific pork carcass. The MQ-25 generates a constant, low-level EM field (2.5MHz) which is sensitive to perturbation by a conductive mass. The amount of EM energy absorbed by the carcass is recorded as it is conveyed through the EM field. Carcasses are mechanically removed from the gambrel and dropped onto a conveyor belt. The conveyor is a flexible belt which conforms to the shape of the EM scanning chamber which is 66cm in diameter and 218cm in length. The "half-circle" orientation of the conveyor allows for consistent placement of the pork carcasses within the EM scanning chamber. Upon exit from the EM scanning chamber, the carcass is manually regambrelled and sent to the chill cooler. This process is completed at a commercial line speed of 350 carcasses per hour.

The MQ-25 generates an electromagnetic scan curve (Figure 1) plotting the phase absorption of a carcass as it passes through the scanning chamber. The curve peaks at the point (PEAK) that the entire lean mass is centred in the field. The curve begins its descent as lean tissue exits the EM field. Analysis of the peak and difference in heights of various points along the curve reveal total lean as well as lean content of the primal cuts. Figure 1 illustrates and defines points used in analysis of the phase absorption curve. An adjusted baseline (AB) is established at a level 10% of the PEAK height from the original baseline. This adjustment eliminates inconsistencies associated with signal noise found at either end of the curve caused by weak EM field strength at the ends of the coil. The intersection of the curve and AB is designated P-0. The point on the abscissa directly below the PEAK is designated P-100. This sets the scale for all points on the curve. Differences between points along the scan curve (based on percentages from P-100) are utilized as predictive indices for primal cuts as they are relative to carcass position within the scan chamber. The scan curve is analyzed in a systematic array with starting points at individual distances from P-100. When these points are identified, differential spacings are tested as independent variables. Figure 1 graphically illustrates $D_{12.5\text{-}37.5}$, which is the curve height difference between two points at 12.5% of scan curve and 37.5% (a 15% spacing between points).

Statistical analysis

The data were analyzed by SAS (1991) linear regression procedures to determine the relationships between total dissected lean (TOTLN), dissected ham lean (HAMLN), dissected loin lean (LOINLN) and dissected lean of the square cut shoulder (SHLN) to measures of TOBEC. Coefficient of determination (R^2) for D values were analyzed using TOTLN, HAMLN, LOINLN and SHLN as dependent variables. The D values with the highest R^2 statistic at each of the 12 percentage spacings were incorporated as independent variables with hot carcass wt, TEMP, LENG and PEAK. Extraneous independent variables were eliminated via stepwise regression. Final equations for the prediction of TOTLN, HAMLN, LOINLN and SHLN were chosen for industrial practicality as well as maximum R^2 and minimum RSD (residual standard deviation).

RESULTS AND DISCUSSION

The means, standard deviations (SD) and coefficients of variation (CV) physical characteristics of pork carcasses (n=50) and EM scan measures are reported in Table 1. Warm carcass wt (HCWT) averaged 82.16 (±7.37)kg. The selection process ensured that an accurate sample of all carcass weights marketed through Sioux-Preme Packing Co. would be represented. Rough-cut ham, loin, picnic shoulder and blade Boston shoulder averaged 9.56 (±0.88), 11.12 (±1.52), 4.54 (±0.50) and 4.07 (±0.45)kg respectively. Primal cuts were separated according to Sioux-Preme processing specifications. Total dissected carcass lean (TOTLN) averaged 19.15 (±2.48)kg yielding an average percentage muscle (%LEAN) of 46.74 (±5.37)%. The mean total dissected carcass fat (TOTFAT) was 14.37 (±3.04)kg calculating to an average percent carcass fat (%FAT) of 34.86 (±5.77)%. Dissected ham, loin and square cut shoulder lean averaged 5.61 (±0.77), 5.33 (±0.76) and 5.11 (±0.63)kg respectively.

Standard linear carcass measurements were obtained at the time of carcass dissection. Last rib fat depth, taken at the split surface of the carcass, has long been a standard estimator of overall carcass lean or percent lean in the United States. The mean last rib fat depth was 28.88 (±7.51)mm. Loin eye area (LEA) was obtained at the third/fourth from last rib interface. This site was chosen (as opposed to 10^{th} rib) because it is the site of choice for optical probe measurements. Loin eye area averaged 35.25 (±5.05)cm^2.

Measurements obtained from TOBEC scans show the peak phase absorption (PEAK) to average 755.5 (±147.7) phase absorption units. The average scan curve length was 155.4 (±3.76). Variation in carcass temperature influences the measuring of TOBEC. This is due to the fact that conductance (1/resistance) will decrease proportionally with temperature (Serway and Faughn, 1988). The MQ-25 was integrated on-line at the end of the slaughter processing line to eliminate fluctuations in carcass temperature stemming from variations in carcass chill. The standard deviation for carcass temperature was well below 1°C (avg. 41.0°; ±.01°C), thus eliminating the necessity for temperature to be accounted for in the forthcoming regression equations.

Table 2 shows simple correlation coefficients for dissected carcass components. Hot carcass weight, fat depths and LEA were only marginally correlated to dissected components. Fat depth measures showed a medium to high correlation to %LEAN and TOTFAT. Points derived from the phase absorption curve had above average to high correlations to lean tissue and low correlations to TOTFAT. This was expected as TOBEC is a measure of the absorption of electromagnetic energy by the conductive portion of the carcass, i.e., lean tissue.

Regression equations for dissected carcass lean and dissected lean of the major primal cuts are listed in Table 3 (equations 1,3,4 and 5). Prediction of total dissected carcass lean (equation 1) from hot carcass wt, PEAK and $D_{0\text{-}17.5}$ was the most statistically efficient (R^2=.904; RSD=1.59kg). The same equation used to predict percentage carcass lean explains 4.1% less variation in %LEAN showing an RSD of 4.10%. A 4.1% predictive error equates to ±3.2kg error per 80kg carcass. The predictive capacity of dissected primal cut lean is very similar for HAMLN (equation 3; R^2=.832; RSD=0.64kg), LOINLN (equation 4; R^2=.862; RSD=0.60kg) and SHLN (equation 5; R^2=.849; RSD=0.51kg).

Equations 6 and 7 are listed for comparative purposes. These equations use independent variables obtained from the National Pork Producers Council's *Procedures to evaluate market hogs* (1991). Equations applying measures of TOBEC show superior statistical efficiency to linear carcass measurements.

CONCLUSION

On-line application of electromagnetic scanning has proven to be plausible for the prediction of total carcass lean as well as lean within the major primal cuts. Regression equations derived from the TOBEC technology are superior in accuracy than traditional equations used to estimate kilograms of quality lean and percent lean. Integration of the on-line scale and EM scanner computer allow for immediate acquisition of weights of quality lean pork. Rapid determination of carcass lean tissue early in the processing line allows the packer the option of sorting carcasses and primal cuts based on lean distribution. Electromagnetic scanning also has the capacity to be used for establishment of an accurate price discovery system (Akridge *et al.*, 1992). A final carcass price my be obtained based on the individual components within the carcass, as opposed to a net carcass or lot price.

REFERENCES

AKRIDGE, J.T., BRORSEN, B.W., WHIPKER, L.D., FORREST, J.C., KUEI, C.H., and SCHINCKEL, A.P. 1991. Evaluation of alternative techniques to determine pork carcass value. *J. Anim. Sci.* 70:18.

FORREST, J.C., KUEI, C.H., CHEN, W., LIN, R.S., SCHINKEL, A.P., WALSTRA, P., KOOPER, H., and JUDGE, M.D. 1991. Electromagnetic scanning: carcass evaluation. p 85. Proc. of the Symposium Electronic Evaluation of Meat in Support of Value-based Marketing. Purdue University.

JONES, S.D.M. 1991. Topic I. Potential and available electronic technologies for quantitative carcass evaluation. Introductory comments. P. 7 in Proc. of the Symposium Electronic Evaluation of Meat in Support of Value-based Marketing. Purdue University.

NATIONAL PORK PRODUCERS COUNCIL. 1991. *Procedures to Evaluate Market Hogs.* 3rd edition. National Pork Producers Council, Des Moines, IA.

SAVELL, J.W., and CROSS, H.R. 1991. Value-based marketing: Current status. *Proc. Rcpr. Meat Conf.* 45:117.

SERWAY, R.A., and FAUGHN, J.S. 1989. *College Physics.* 2nd edition. Saunders College Publishing, Chicago, IL.

Table 1. Physical characteristics and EM scan measures (n=50).

Variable[a]	Mean	SD	Range	CV, %
Warm carcass wt, kg	82.16	7.37	68.95-99.79	8.97
Rough-cut ham et, kg	9.56	0.88	7.62-11.75	8.41
Rough-cut loi wt, kg	11.12	1.52	8.35-14.74	13.67
Rough-cut picnic shldr wt, kg	4.54	0.50	3.76-6.12	11.01
Rough-cut blade-boston wt, kg	4.07	0.45	3.13-5.49	11.06
TOTLN, kg	19.15	2.48	13.29-25.22	12.95
%LEAN	46.74	5.37	30.05-57.26	11.49
TOTALFAT, kg	14.37	3.04	9.57-24.27	21.16
%FAT	34.86	5.77	3.86-7.62	16.55
HAMLN, kg	5.61	0.77	3.76-7.12	13.73
LOINLN, kg	5.33	0.77	3.90-6.67	14.82
SHLN, kg	5.11	0.79	17.78-48.26	12.33
Last rib fat depth, mm	28.88	0.63	19.61-45.03	26.00
LEA, cm²	35.25	7.51	127-144	14.33
Length	155.4	3.76	450-1176	2.42
PEAK	755.5	147.7	40.3-41.9	19.55
Temperature, °C	41.0	0.01		0.02

[a] TOTLN = kg of total dissected carcass lean
%LEAN = TOTLN/hot carcass wt
TOTFAT = kg of total dissected carcass fat
%FAT = TOTFAT/hot carcass wt
HAMLN = kg of dissected ham lean
LOINLN = kg of dissected loin lean
SHLN = kg of dissected lean from blade-boston, picnic shoulder and neck bone area
LEA = loin eye area
Length = length of the phase absorption scan curve
PEAK = phase absorbance peak value

Table 2. Simple correlation coefficients for carcass measurements and dissected carcass lean components (n=50).

	TOTLN	%LEAN	TOTFAT
Hot carcass wt	.469**	-.246	.626***
HAMLN	.949***	.737***	-.349*
LOINLN	.926***	.642***	-.270
SHLN	.954***	.714***	-.358*
Last rib fat depth	-.481***	-.771***	.786***
3rd last rib fat depth	-.471***	-.850***	.919***
LEA	.792***	.558***	-.272
Length	.575***	.376**	-.100
PEAK	.928***	.726***	-.430**
$D_{0-17.5}$	.880***	.750***	-.449**
$A_{90-97.5}$	.934***	.720***	-.418**
$D_{97.5-130}$	.537***	.699***	-.659***
$D_{5-32.5}$	.935***	.734***	-.426**
$D_{25-52.5}$	.593***	.291*	-.091

Table 2 (cont). Simple correlation coefficients for carcass measurements and dissected carcass lean components (n=50).

	HAMLN	LOINLN	SHLN
Hot carcass wt	.398**	.483***	.432**
HAMLN	1.00	.839***	.890***
LOINLN	.839***	1.00	.833***
SHLN	.890***	.833***	1.00
Last rib fat depth	-.491***	-.416**	-.476***
3rd last rib fat depth	-.472***	-.381**	-.461***
LEA	.766***	.751***	.711***
Length	.553***	.638***	.472***
PEAK	.887***	.857***	.894***
$D_{0-17.5}$	.812***	.856***	.845***
$A_{90-97.5}$	.890***	.864***	.897***
$D_{97.5-130}$	.463***	.500***	.556***
$D_{5-32.5}$	.880***	.908***	.884***
$D_{25-52.5}$	.528***	.531***	.566***

*** $P<0.001$; ** $P<0.01$; * $P<0.05$

TOTLN = kg of total dissected carcass lean
%LEAN = TOTLN/hot carcass wt
TOTFAT = kg of total dissected carcass fat
HAMLN = kg of dissected ham lean
LOINLN = kg of dissected loin lean
SHLN = kg of dissected lean from blade-boston, picnic shoulder and neck bone area
PEAK = phase absorbance peak value
$D_{0-17.5}$ = difference in phase absorption curve heights at 0 and 17.5% of the scan curve
$A_{90-97.5}$ = area under the curve at 90 and 97.5% of the scan curve
$D_{97.5-130}$ = difference in phase absorption curve heights at 97.5 and 130% of the scan curve
$D_{5-32.5}$ = difference between points on the phase absorption curve heights at 5 and 32.5% of the scan curve
$D_{25-52.5}$ = difference between points on the phase absorption curve at 25 and 52.5% of the scan curve

Table 3. Regression equations for predicting total dissected carcass lean and dissected lean of the major primal cuts.

Means of pred./ Depend't var'ble/ equation	Independent variable	Int'cpt	b-value	R^2	RSD
MQ-25					
TOBEC					
TOTLN 1		6.89*		.904	1.59
	Hot carcass wt		.111**		(kg)
	+ PEAK		.020***		
	+ $D_{0-17.5}$		.050**		
%LEAN 2		109.9***		.863	2.05
	Hot carcass wt		-.836***		(%)
	+ PEAK		.045***		
	+ $D_{0-17.5}$		.122*		
HAMLN 3		4.19***		.832	0.64
	$A_{90-97.5}$		.002***		(kg)
	+ $D_{0-17.5}$		.013*		
	+ $D_{97-5-130}$		-.012*		
LOINLN 4		1.39		.862	0.60
	Hot carcass wt		.046***		(kg)
	+ $D_{5-32.5}$		.023***		
	+ $D_{25-52.5}$		-.005*		
SHLN 5		9.64*		.849	0.51
	Hot carcass wt		.028*		(kg)
	+ PEAK		.006***		
	+ Length		-.059*		
	+ $D_{0-17.5}$		.013*		
			.300***		
			.00.5**		
			-.327*		
			-.412**		
			.011***		
			-.747***		

Standard carcass linear meas.					
TOTLN 6	Hot carcass wt + LEA + Last rib fat	7.05	.300*** .005** -.327*	.815	2.20 (kg)
%LEAN 7	Hot carcass wt + LEA + Last rib fat	109.9***	-.412** .011*** -.747***	.763	2.70 (kg)

*** P<0.001; ** P<0.01; * P<0.05.
See Table 2 footnotes.