ELECTROMAGNETIC SCANNING, ULTRASONIC IMAGING AND ELECTRONIC PROBING FOR ESTIMATION OF PORK CARCASS COMPOSITION.

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SUMMARY

Application of biomedical electronic technology to determine lean to fat ratio in live animals or carcasses offers potential for improved precision in meat animal evaluation. Gilts and barrows weighing 80 to 149 kg were randomly selected from commercial buying stations in the state of Indiana, USA, and transported to the Purdue University Meat Science Laboratory for slaughter. Prior to slaughter, each pig was scanned with an ultrasound probe and images of fat depth and loun muscle area recorded. Carcasses were introduced into an electromagnetic scanner as dehaired uneviscerated whole carcasses, as eviscerated right warm carcass sides and as chilled right sides. Right warm sides were scanned with an ultrasound probe. Chilled right carcass sides were probed at the 10th rib with an optical electronic probe for fat and muscle depth. Carcass measurements were made on right sides for midline fat thickness over the first and last ribs and last lumbar vertebrae, then ribbed at the 10th and last ribs for 3/4 fat depth and loin muscle area measurements. Right carcass sides were then weighed, divided into trimmed standard US industry primal cuts. Primal cuts and all other carcass parts were dissected into lean, fat and bone. Ether extraction was performed on samples of dissected lean. Regression analysis to predict total dissected carcass lean revealed that the electronic signal from the electromagnetic scanner, carcass length and carcass temperature combined to give an R^2 of .913. Carcass ultrasound images of fat depth and loin muscle area at the 10th rib and warm carcass weight gave an R^2 of .827. The electronic probe for fat and muscle depth at the 10th rib of chilled carcasses combined with the chiled carcass weight give an R^2 of .826. The R^2 is .849 when actual loin muscle area and fat depth are measured in the ribbed carcass and combined with warm carcass weight.

INTRODUCTION

Accurate and rapid determination of carcass value and composition under industrial conditions represents a challenge to the meat and livestock industry. Production systems must continuously be adjusted to meet consumer demands. Pricing systems that are sensitive to demand provide a communication link that ultimately determines which genetic, nutrition and management regimes will be used in producing raw materials for the world meat supply. A number of useful evaluation systems have been developed and applied in several countries. However, advancements in slaughter technology have dramatically increased line speeds, creating a need for automated systems. Biomedical technology combined with advanced high speed computer technology to determine fat to lean ratio in live animals or carcasses offers potential for improved precision in meat animal evaluation and pricing.

The objectives of on-going studies at Purdue University are to: (1) determine feasibility and accuracy of selected electronic instruments in determining pork carcass composition, (2) establish a pork composition data base which can be used to test various prediction equations and to design model merchandising programs which allow optimal fabrication of carcass parts based on composition, and (3) develop models for accurate price discovery systems based on value of saleable cuts. This paper deals mainly with the first objective.

MATERIALS AND METHODS

Gilts and barrows weighing 80 to 149 kg were randomly selected from commercial buying stations, cooperating swine herds, and the Purdue University swine research herd, and transported to the Purdue University Meat Science Laboratory for slaughter. Prior to slaughter, the right side of each pig was scanned with an Aloka Corometrics 210DX Real-Time Ultrasound Scanner. Images were recorded for subsequent measurement of fat depth at the midline over the first rib, last rib and last lumbar vertebra as well as over the loin at the 10th and last ribs for 3/4 fat depth. Loin muscle area readings were taken from ultrasound scans at the 10th and last ribs. Animals were weighed and exsanguinated. Weights of blood and individual by-products were recorded. Carcasses were scalded and dehaired. Uneviscerated carcasses were introduced into a Dj Medical Corporation, HA-2 Electromagnetic Scanner (TOBEC). Carcasses were eviscerated and split. The right side of each warm carcass was subjected to ultrasound scans over the loin at the l0th and last ribs for 3/4 fat depth and loin muscle area measurements. Warm right sides were introduced into the TOBEC. Carcasses were chilled overnight at 2oC. After chilling, right carcass sides were again introduced into the TOBEC. Chilled right sides were probed with an optical electronic probe, (Destron PG 100 Pork Grader), posterior to the 10th rib and 7cm from the midline. Carcass fat depth was measured on right sides with a ruler over the midline opposite the first rib, last rib and last lumbar vertebra, then over the loin (3/4 fat depth) at the 10th and last ribs. Loin muscle area was measured with a dot grid at the 10th and last ribs.

The right side of each carcass was fabricated into trimmed wholesale cuts as described by the Pork Carcass Evaluation Committee in the 1952 Proceedings of the

Table 1. Means and standard deviations for 412 market hogs.

Variable	Mean	SD
Live weight (kg)	104.81	8.44
Warm carcass weight (kg)	77.98	6.69
Chilled right side weight (kg)	38.39	3.27
Loin muscle area (cm^2)	31.60	4.95
Fat depth, 10th rib 3/4 (cm)	2.92	.75
Backfat, last rib (cm)	2.56	.61
Total dissected lean (kg) (Adjusted 10% Fat) (Right side)	18.75	2.43
Percent dissected lean (Adjusted 10% Fat) (Right side)	49.27	5.18

Table 2. Correlations of live and carcass ultrasonic measurements with weight and percent dissectible lean and actual fat and muscle measurements (n=208).

	Total weight dissected lean (10% fat)	Dissected percent lean (10% fat)	Fat depth 10th Rib 3/4	Loin muscle area
Live ultrasound fat measurement				
1st rib	-.31	-.73	.72	-.19
10th rib 3/4	-.35	-.77	.89	-.25
Last rib	-.32	-.62	.65	-.18
Last lumbar	-.27	-.73	.82	-.10
Live ultrasound loin muscle area				
10th rib	.54	.35	-.19	.60
Last rib	.47	.35	-.21	.58
Carcass ultrasound fat measurement				
10th rib 3/4	-.40	-.81	.91	-.27
Last rib	-.27	-.66	.72	-.10
Carcass ultrasound loin muscle area				
10th rib	.56	.44	-.32	.63
Last rib	.55	.47	-.35	.62
Actual measurement				
Warm carcass weight	.56	-.18	.29	.38
Loin muscle area	.74	.49	-.43	.---
Fat depth, 10th rib 3/4	-.39	-.81	.---	.---

Table 3. Regression equations for predicting total weight of lean adjusted to 10% fat.

		b Value	R^2	RSD
Direct carcass measurement				
Intercept	4.92		.812	2.07
Loin muscle area		+ .30		
Fat depth, 10th rib 3/4		-3.40		
Warm carcass weight		+ .43		
Live ultrasound measurement				
Intercept	4.66		.635	2.81
Loin muscle area		+ .26		
Fat depth		-3.42		
Live weight		+ .33		
Carcass ultrasound measurement				
Intercept	5.44		.787	2.20
Loin muscle area		+ .16		
Fat depth		-3.88		
Warm carcass weight		+ .50		

Reciprocal Meat Conference. The weight of each trimmed primal cut was recorded as well as all trimmed lean, fat, bone and skin. Composition of each primal cut was determined by physical dissection into lean, fat, bone and skin. Fat content of all dissectible lean was determined by ether extraction. Carcass lean was standardized to a fat constant of 10% as described by Fahey et al. (1977). Analysis of variance, multiple linear regressions and correlation coefficients were computed using SAS (1985).

RESULTS

Means and standard deviations characterize the population of animals used in these studies (Table 1). A subsample of this population was used with each instrument.

The TOBEC measures lean body mass using the principle of total body electrical conductivity reviewed by Boileau (1988). Carcasses move through a 2.5 MHz coil electromagnetic field on a motor-driven sled at a constant rate. Conductivity is measured at 64 equidistant intervals as the carcass moves through the length of the coil. Measured conductance and capacitance of the carcass is displayed on a phase/angle distance curve. Regression analysis to predict weight of total dissected carcass lean revealed that the electronic signal from TOBEC, combined with carcass length and carcass temperature, gives an R2 of .913 with an RSD of .69 (n = 132). This result agrees with a correlation of .976 between TOBEC phase average and empty body lean mass reported by Keim et al. (1986) on 25 live, anesthetized, 87kg-weight pigs. Further analysis of these data are being conducted to determine the potential ability of this technology to measure yield and composition of major primal cuts. The precision with which total lean mass is measured suggests that this technology has excellent potential for application in carcass-merit-based price discovery systems.

Real-time ultrasonic devices may be useful in evaluating composition of seedstock animals or for evaluation of market animals to determine optimal market weight. With proper engineering and adaptation, ultrasound also may be useful in evaluating carcasses on the slaughter line. Table 2 shows the correlation coefficients of various live and carcass ultrasound measurements with both weight and percent of fat adjusted dissectible lean as well as with actual fat and muscle measurements.

Regression equations using three-variable models are presented in Table 3. Real-time ultrasonic measurements of loin muscle area and fat depth at the 10th rib on warm carcasses appear to be nearly as precise at predicting lean muscle mass as actual measurements made on chilled carcasses.

The electronic probe for fat and muscle depth offers ease of application, relatively low cost and immediate availability, and has been approved for application in many countries. Electronic probe measurement of fat and muscle depth at the 10th rib of chilled carcasses combined with chilled carcass weight give an R^2 of .826 with an RSD of .91 (n = 170).

DISCUSSION

In a consumer driven industry that depends upon a loosely linked production chain typical of the pork and beef industries in the USA, it is sometimes difficult to communicate consumer demands accurately throughout the chain. The most effective incentive to adjust production systems to meet consumer desires comes in the form of a monetary differentials. The main obstacle to establishing realistic price differentials is unavailability of rapid and accurate techniques for determining raw material values when product is transferred from one segment of the industry to another. A critical transfer point is between livestock producers and slaughterers. Price differentials based upon carcass value have major impact on genetic selection and management programs. Both quality and composition of carcasses must be evaluated, but, this paper deals only with evaluation of carcass composition. Topel and Kauffman (1988) reviewed more than thirty techniques for estimating live animal or carcass composition. We have selected three such techniques that hold promise for application over both short and long terms. The electronic probe has already gained wide acceptance in many parts of the world and offers the industry a short term solution to carcass evaluation. Topel and Kauffman (1988) concluded that the combination of weight, carcass length and light reflectance probe measurements correlates well (R^2 = 0.77) with muscle percent. Personal communication with various sources in several countries suggests a range from R^2 0.87 (RSD 1.79) to R^2 0.66 (RSD 2.09) in predicting pork carcass lean composition with several probe designs. Our study is continuing and additional probe instruments will be evaluated.

Current real-time ultrasound imaging devices developed by the biomedical industry offer potential for adaptation by the meat and livestock industry. The ability to evaluate live animals provides a powerful tool for added precision in genetic selection. Development of robotics and computerized image analysis would make this technology potentially applicable to the slaughter industry.

Electromagnetic scanning for total body electrical conductivity to evaluate lean body mass merits further study. Cochran et al. (1986) found that the fat free mass in human infants ranging in age from 2 to 291 days determined by TOBEC correlated well (r = .949) with the fat free body mass as calculated from total body water measurements. Studies with both human and animal models indicate that the method can be applied to a variety of subjects with good prediction precision (Boileau 1988). With further development, this technique may offer rapid, non invasive and accurate determination of total carcass lean as well as differentiation of lean mass within regions of the carcass to allow further refinement value determination.

CONCLUSIONS

Technology exists for further development of highly sophisticated, accurate, rapid methods for determination of carcass composition and value in modern high volume slaughter facilities. This research has established that a high level of accuracy can be achieved with electromagnetic scanning. Engineering and design of prototype instruments for the slaughter industry now may be undertaken. Establishment of economic parameters for applying this technology in model price discovery systems is underway.

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