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ELASTOGRAPHY TO PREDICT PORK QUALITY

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INTRODUCTION: Pork quality objective assessment has been defined as a high priority. Pale, soft and exudative (PSE) or dark, firm and dry (DFD) meat are two of the most prevalent pork quality problems. A recently conducted survey (Kauffman et al., 1992) indicated that 26% of the slaughter hog population in 14 major US packing plants showed undesirable quality characteristics, such as PSE (16%) and DFD (10%). An accurate method for identifying PSE in pork directly on the slaughter line would enable the packer to include a price differential in the value system for pork. The objective of this study was to determine if information, either qualitative or quantitative, derived from elastography could be used to detect or predict pork quality differences in two ham muscles.

MATERIALS AND METHODS: Hams (n=40) were evaluated 24 h after slaughter using pork quality standards (NPPC, 1991) for variations in color, firmness and moisture at the anterior lean cut surface. PSE, DFD, red, soft and exudative (RSE) and normal grayish-pink color with normal lean texture hams were used as treatments (n=10 per treatment). Two muscles, Biceps femoris (Bf) and Semimembranosus (Sm), were excised from each ham. A 50x50x30 mm block was obtained from the center of each muscle for elastography analyses. From the remaining muscle, a 2.5 cm steak was removed and Hunter L*, a* and b* values. A mirror-image steak was used for sensory color determination using a 10-member trained meat color descriptive attribute panel for lean color (5=very firm and dry; 1=pale pinkish gray) and lean firmness (5=very firm and dry; 1=very soft and very watery). The remainder of each muscle was composited and pH, water holding capacity (WHC), and fat (%) and moisture (%) analyses were completed. WHC was determined as defined by Rubio (1995). Percentage of fat and moisture and pH were determined (AOAC, 1990). For elastography analysis, a standard foam material that was structureless, homogeneous, and with viscoelastic behavior within the range of the samples and that provided contrast to meat samples in elastograms was used to measure the local strain of each image. The foam was placed below the meat and they were evaluated under water (2-3°C). Elastography was performed as described by Ophir et al. (1991). A new method to improve the quality of the images was implemented as described by (Céspedes and Ophir, 1993). The resulting image was converted to a gray scale of 0% (black) and 3% (white) strain. Elastography ratio was calculated from each image as the ratio of the foam strain and the meat strain. Images, meat only, were subjected to a texture extraction process (Haralick et al., 1973). Fourteen gray-level cooccurance matrix statistical texture parameters (GCCM parameters) were extracted from each image at four angles (0, 45, 90 and 135; all angles were averaged) and four neighborhood distances (1, 2, 5, and 10). Statistical analysis were performed using the GLM procedure of SAS (1991) and means were separated with Tukey Studentized Range test (p<05). Simple correlation coefficients between independent and dependent variables were obtained and linear regression equations for predicting quality and compositional characteristics were developed by maximum R-square (R^2) and minimum standard error of the estimate (SEE) improvement techniques using the stepwise linear regression method (SAS, 1991; P<.15). Because data for this study are continuous, classificatory discriminant analysis was used (Silverman, 1986).

RESULTS AND DISCUSSION: The Bf was redder (Hunter a* = 5.0) than the Sm (Hunter a* = 3.8) and muscles classified as PSE were lighter in color (lean color = 1.9; Hunter L* = 42.1), had lower moisture (74.4%) and lower pH (5.5) than muscles classified as DFD (3.1, 34.0, 75.4 and 6.1, respectively). Similar studies have reported that PSE meat is associated with high Hunter L* and b* values, but do not differ in a* measurements (Chizzolini et al., 1993). RSE muscles tended to be slightly darker red (lean color = 2.9, Hunter L* = 35.3, Hunter b* = 6.7) than normal muscles (lean color = 2.4, Hunter L* = 38.2, Hunter b* = 8.5) and RSE muscles had lower pH (5.9) than DFD muscles (6.1). The aforementioned differences in lean color and pH indicated that quality classifications in this study were acceptable to address the objectives of the study. Elastography ratio did not differ (p>.05) across muscles (1.8 and 1.0 for Sm and Bf muscles, respectively) and quality categories (2.2, 1.1, 1.6 and 0.9 for normal, PSE, DFD and RSE muscles, respectively); however, elastography ratio accurately classified 20% of PSE and DFD samples, and 65% of RSE samples using descriminant analysis (Table 2). Either elastography ratio was not sensitive to differences between quality classes or quality differences among these groups were not reflected in muscle softness. Standard deviations for elastography ratio were higher for normal samples and Sm muscles. Visual examination of the elastograms showed that contrast between foam and meat in DFD muscles was greater than the contrast in either normal, PSE or RSE muscles indicating that DFD samples were less soft than the other three quality classes. As elastography ratio increased WHC decreased (r=-.69). In PSE samples, moisture was correlated with elastography ratio (r=-.56). In DFD muscle, elastography ratio was highly correlated to WHC (r=-.50) and pH (r=-.52). In normal samples, elastography ratio had a low correlation with L*, a* and moisture. In summary, as elastography ratio increased, lean color, lean firmness, WHC, moisture and pH decreased and as elastography ratio increased, L*, b* and fat percentage increased. In a second analysis, texture parameters were calculated from elastograms and used to predict pork quality parameters using linear regression (Table 1). Texture parameters from PSE samples were highly correlated to firmness and WHC. On the other hand, texture parameters from DFD samples were highly correlated to lean color and the chemical, sensory and mechanical attributes of pork muscle. Regression equations for normal muscles showed that color and WHC were highly predictable; however lean color, b* value and fat were not highly predictable using GCCM parameters. For PSE muscles, regression equations using GCCM parameter were highly predictive of pH, firmness and fat. Regression equations using DFD muscles were highly predictive for a* values and WHC, whereas regression equations for WHC from RSE muscles had an R^2 of 88% and greater than 60% of the variation in other quality attributes. Discriminant analysis (Table 2) indicated that elastography ratio and GCCM parameters could correctly classify PSE (70%) and DFD (60%) muscles, however, normal and RSE muscles had higher rates of misclassification. Kauffman et al. (1993) used discriminant analysis and they found a 57% classification rate. When elastography ratio was introduced into the equation, the accuracy for PSE samples increased to 85%, but decreased for DFD (57%) and RSE (15%). When elastography ratio was used alone, 20% of PSE, 21% of DFD and 65% of RSE samples were accurately classified.

CONCLUSIONS: Quantitative elastography was not successful in detecting or predicting differences in quality groups for pork muscles; however, qualitative elastography was able to differentiate the elasticity differences among pork quality classes. Therefore, elastography has potential to be a non-intrusive, instrumentation tool for determining differences among pork quality groups; however, further research is needed to improve the efficacy of quantitative elastography to automatically detect pork quality defects.

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Table 1. Prediction equations for chemical and sensory attributes for Bf and Sm muscle from normal, PSE, RSE or DFD pork hams.

	Normal		PSE		DFD		RSE	
Dependent Variable[a]	R^2	SEE	R^2	SEE	R^2	SEE	R^2	SEE
Lean color	.09	.40	.41	.26	NS	NS	.60	.32
Lean firmness	.40	.32	.84	.19	.37	.35	.74	1.23
Hunter L*	.55	2.62	.60	1.72	.40	2.49	.50	2.00
Hunter a*	.68	.78	.53	.82	.89	.43	.66	.69
Hunter b*	.20	.86	.50	.64	.34	.58	.86	.31
Water holding capacity	.73	4.70	.64	3.39	.81	3.66	.88	3.31
Fat, %	.16	1.41	.78	1.10	.75	.59	.92	.35
Moisture, %	.74	.53	.78	.79	.08	.51	.67	.76
pH	.25	.20	.89	.05	.60	.19	.66	.12

NS = Not significant at P<.15.

Table 2. Percentage of samples from Bf and Sm muscles and from PSE, DFD, RSE and normal pork hams classified into the predicted treatment groups defined by the elastography ratio, GCCM paramters averaged by distances, and GCCM parameters at each distance.

Actual	Predicted Groups using Elastography Ratio				Predicted Groups using GCCM parameters averaged by distances				Predicted Groups using GCCM parameters at each of the distances			
Treatments	Normal	PSE	DFD	RSE	Normal	PSE	DFD	RSE	Normal	PSE	DFD	RSE
Normal	10.00	10.00	20.00	55.00	50.00	18.06	9.72	22.22	51.39	19.44	11.11	18.06
PSE	15.00	20.00	15.00	50.00	22.22	29.17	22.22	26.39	13.84	54.17	19.44	12.50
DFD	21.05	21.05	21.05	36.84	20.59	27.94	35.29	16.18	10.29	17.65	52.94	19.12
RSE	5.00	30.00	0.00	65.00	20.00	20.00	10.00	50.00	18.33	21.67	30.00	30.00