A Novel Laser Air Puff and Shape Profile Method for Predicting Tenderness of Broiler Breast Meat

Y. S. Lee,*[1] C. M. Owens,† and J. F. Meullenet*[1]

*University of Arkansas, Food Science, Fayetteville 72704; and †University of Arkansas, Poultry Science, Fayetteville 72704

ABSTRACT The potential application of a new laser air puff system to assess poultry meat tenderness was investigated. Ninety broilers were deboned at either 1.25, 4, or 24 h postmortem. The raw breast fillets were scanned on a conveyor belt longitudinally by a laser distance sensor to obtain overall shape profiles and scanned again with a pressurized source of air (206.8 kPa). The 2 resulting profiles were superimposed to quantify the amount of deformation caused by the application of pressurized air. Five parameters including a height and length of each fillet were calculated and used to establish a model to predict tenderness. Tenderness of cooked fillets was determined instrumentally with the Meullenet-Owens razor shear, Blunt-Meullenet-Owens razor shear, and with sensory analysis. Hardness, Meullenet-Owens razor shear energy, and Blunt-Meullenet-Owens razor shear energy were modeled with the parameters extracted from the air puff system. Predicted values obtained from the models and observed values of individual fillets were subjected to logistic regression to classify fillets into tenderness levels. Tender fillets in the air puff predicted tender group represented 82, 81, and 88% based on hardness, Meullenet-Owens razor shear energy, and Blunt-Meullenet-Owens razor shear energy, respectively. The use of this tool resulted in more than a 20% improvement in the number of tender fillets after classification. The results suggested that this new system could potentially be implemented as an online tool for sorting poultry breast fillets by tenderness levels.

Key words: air puff, shape profile, tenderness, broiler breast meat, Meullenet-Owens razor shear

2008 Poultry Science 87:1451–1457
doi:10.3382/ps.2007-00463

INTRODUCTION

The production of boneless, skinless broiler breast meat has remarkably increased over recent years due to increased consumer demand (Jones and Grey, 1989; Cavitt and Sams, 2003). However, the incidence of tough broiler breast meat is a significant issue in the poultry industry, because tenderness is known to be a predominant factor in determining meat quality and consumer eating satisfaction (James, 2002). Accordingly, the need to meet consumer expectations and increased recognition of the importance of tenderness has led to the development of various instrumental methods designed to assess meat tenderness.

Instrumental methods that assess poultry meat tenderness can be broadly classified into 2 categories: destructive and nondestructive. Destructive methods such as the Warner-Bratzler shear, Allo-Kramer shear, and Meullenet-Owens razor shear (**MORS**) require sample cooking, cutting, or mechanical shearing and are not suitable for online classification of tender and tough fresh meat. As a result, destructive methods have been employed for sampling purposes only. Nondestructive methods, which include near-infrared reflectance analysis and image analysis, can also be unsuited to online usage due to their high cost or lack of reliability, or both. Therefore, there is a need for an economically feasible, nondestructive instrumental method that will determine fresh meat tenderness levels in an online production environment. Such a method would have to be fast, cost-effective, as well as easy to implement in a commercial situation.

Some success in finding such a method has been achieved through the introduction of a novel shape profile method that correlated poultry breast meat dimensions with tenderness (Meullenet et al., 2005). It was observed that tenderness decreased as the fillet thickness increased, but tenderness increased as the length and width increased (Meullenet et al., 2005). In this research, 130 fillets were classified into tenderness levels with a correct classification rate of 83.1%. As a means of increasing the correct classification rate, the shape profiling method and a laser air puff technique could be integrated. The air puff system employs a source of pressurized air that causes deformations on the surface of the product to predict firmness, which could indicate poultry meat tenderness. The air puff system has the added feature of not requiring contact

Received November 17, 2007.
Accepted March 28, 2008.
[1]Corresponding author: JFMEULL@uark.edu

with a sample, which has significant advantages from a food safety standpoint. Though it has been successfully applied to predict fruit firmness (Prussia et al., 1993; McGlone et al., 1999; Prussia and Hung, 2001), the air puff system has not yet been tested for meat tenderness.

The objectives of this research were to (1) introduce a laser air puff system capable of being implemented for online assessment for poultry meat tenderness and to (2) examine the potential application of this system as a nondestructive tenderness sensor. The application of this type of technology in the poultry industry would identify naturally tender breast meat, which could potentially be retailed at a premium price.

MATERIALS AND METHODS

Poultry Processing

A total of 90 commercially raised 7-wk-old broilers were purchased from a local producer and 1 h before processing were transported to the University of Arkansas poultry processing plant in Fayetteville. The birds were evenly divided into 6 lots of 15 birds, and each lot was assigned to 1.25, 4, or 24 h postmortem (**PM**) deboning time with 2 replications. After a 10-h feed withdrawal before slaughter, the birds were hung on an automatic shackle line and commercially processed at 20-min intervals. The birds were electrically stunned (11 V, 11 mA, 10 s), manually cut (severed left carotid artery and jugular vein), bled out (1.5 min), scalded (55°C, 2 min), and picked inline using commercial defeathering equipment (Foodcraft Gent-L-Flex GTF 3 Bank chicken-turkey picker, LB Products, Libertyville, IA). Evisceration was conducted manually, after which the birds were chilled using a 2-stage chilling regimen consisting of a 0.25-h prechill at 10°C and 0.75 h chill at 0°C in an ice-water mixture tank. Carcasses were then aged on ice (<2°C) after the chilling period until the deboning time. Both the right and left pectoralis major muscles were excised based on the technique of Hamm (1981) at 1.25, 4, or 24 h PM to provide a wide variety of fillet tenderness. The excess skin of the deboned breast fillets was trimmed. All deboned fillets were frozen after 24 h PM and used for the experiment within a month. Half of each individual fillet was used as an experimental unit in this study.

Laser Air Deformation System

The major components of the laser air deformation system were a source of pressurized air, a solenoid switching valve, an outlet nozzle, a laser displacement sensor, a conveyor belt, and a portable computer. The pressurized air was available with the range of 34.5 and 413.7 kPa, which was regulated by a solenoid switching valve. The emitter in the laser displacement sensor (L-GAGE Q50A-VUQ, Banner Engineering Corp., Minneapolis, MN) was located right above the nozzle of the air puff system so that the laser and the jet of air were targeted at the same position on each fillet. Figure 1 shows the scheme of the laser air deformation system used for the present study. The sensing range of the laser displacement sensor was between 50 to 150 mm with a resolution of 0.1 mm. The laser sensor had a visible red beam. Data acquisition and all instrumental controls were assisted with a computerized system designed with specialized software (Labview Version 6, National Instruments Corp., Austin, TX).

Figure 1. The scheme of a laser air deformation system.

Raw, frozen breast fillets randomly selected from each treatment were thawed overnight in a refrigerator (3 ± 1°C) before being subjected to the air puff system. The thawed fillets were scanned by a fixed laser distance sensor while traveling on a conveyor belt longitudinally to obtain overall shape profiles and then rescanned with simultaneous application of a pressurized source of air (206.8 kPa). Through a preliminary study, it was determined that deboned breast fillets were best discriminated within the range of 172.4 to 241.3 kPa of air (data not shown). This was done by studying the deformation imparted to the 2 or 6 h PM deboned meat by air at pressures varying between 103.4 and 344.7 kPa.

The 2 shape profiles of fillets obtained with and without the application of pressurized air were plotted as distance versus amplitude and then superimposed to quantify the differences between the 2 profiles (Figure 2). It has been reported that approximately 5% of red visible laser beam reflections are lost for objects that are red, orange, or yellow compared with objects in white (Banner Engineering Corp., 2007). Therefore, because raw breast fillets are comprised of red, orange, and yellow colors, the individual fillets were covered with a white plastic film to ensure that the laser beam was completely reflected and that the complete shape profile was recorded during the entire experiment. Fillets were placed on a designated line of a cutting board to make sure that the exact same portion of the fillets was scanned through the 2 laser sensor passes. The Spline function in JMP was used to smooth the profile curves of each fillet. Specific macrofunctions were created to calculate the parameters from

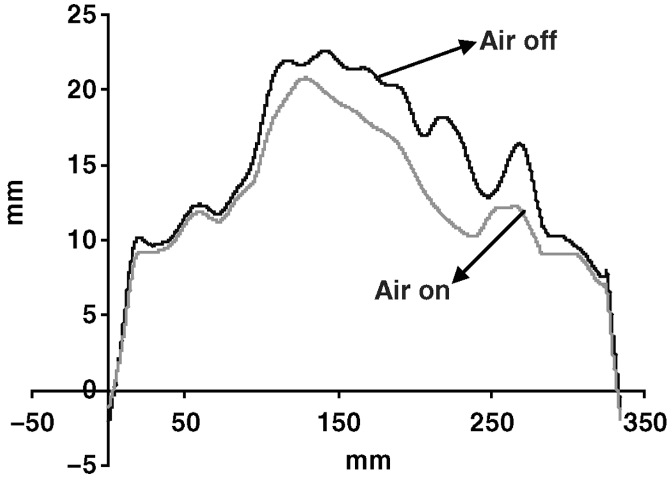

Figure 2. A typical shape profile curve of a breast fillet using the laser air deformation system.

the air puff system. This macro was tested several times with simple cases to validate its accuracy before its application. The 5 parameters extracted from the difference between the profiles obtained with and without the application of pressurized air were as follows: the total area difference, the area difference above a height of 15 mm, the area difference above a height of 20 mm, the area difference up to maximum peak, and the maximum peak difference (Table 1). All extracted parameters, including the heights and lengths of each fillet, were used to develop models to predict tenderness. In an online application, 2 different identical laser distance sensors in series consisting of the fist sensor without air and the second one with air application to fillets would be employed.

Cooking

Following the air deformation system analysis, fillets were covered with aluminum foil, placed in pans, and were cooked on racks in an air convection oven (Maytag Gemini Model, Maytag Corp., Newton, IA) at 176°C. Fillets were cut longitudinally in half immediately after the center of the fillet had reached an internal endpoint temperature of 76°C, which was determined using a digital thermometer (Model 51 II thermometer, Fluke Corp., Everett, WA). For each fillet, the left halves were subjected to sensory analysis, whereas the right halves were individually wrapped in foil and stored overnight at 3 ± 1°C and subjected to instrumental analysis the next day.

MORS and Blunt MORS Analysis

The tenderness of right halves was measured by both MORS and Blunt MORS (**BMORS**) with a texture analyzer (Model TA-XT2*Plus,* Texture Technologies, Scarsdale, NY) as discussed by Cavitt et al. (2004) and Meullenet et al. (2004). Meullenet-Owens razor shear was introduced as an alternative instrumental method being advantageous with quicker, simpler, and similar performance for the prediction of poultry meat tenderness to the Warner-Bratzler shear and Allo-Kramer shear (Cavitt et al., 2004, 2005; Meullenet et al., 2004). Blunt MORS is a modified version of MORS that is designed to improve discrimination among tough meat as well as circumventing the necessity of shearing blade replacement (Meullenet et al., 2004). The MORS force (N) and MORS energy (N × mm; **MORSE**) and the BMORS force (N) and BMORS energy (N × mm; **BMORSE**) were determined and used as instrumental predictors of meat tenderness.

Descriptive Analysis

Sensory analysis was conducted by 7 trained meat descriptive panelists trained by the Spectrum method (Sensory Spectrum Inc., Chatham, NJ) on 4 different days. The panelists had extensive experience with meat descriptive analysis at least 100 h, and only a short orientation on the products to be tested was necessary. On each testing day, 6 individual fillets from each of the 3 treatments within 2 replications were cooked, and five 1/2-in. (1.3 cm) pieces were prepared from each individual fillet. The pieces were presented to each panelist with references as summarized in Table 2. The treatment presentation order among panelists was completely randomized. Between each sample, panelists were instructed to cleanse their palate with water and crackers. Initial hardness from the first bite stage, hardness of mass, cohesiveness of mass, and number of chews just before swallowing from the chewdown stage were evaluated based on 15-point numerical scales with references of assigned intensities.

Statistical Analysis

Instrumental data were subjected to a 1-way ANOVA using the GLM procedures of SAS (SAS version 9.1., SAS Institute Inc., Cary, NC). Least significance difference was used to separate the means at a significance level of 0.05. Two-way ANOVA was performed for sensory data using PROC MIXED of SAS treating deboning time as fixed

Table 1. Parameters extracted from the air deformation and shape profile method

Parameter	Unit	Definition
TAD	mm^2	Total area difference between 2 profiles
AD15	mm^2	Area difference above height of 15 mm between 2 profiles
AD20	mm^2	Area difference above height of 20 mm between 2 profiles
ADM	mm^2	Area difference up to maximum peak between 2 profiles
MPD	mm	Maximum peak difference of 2 profiles

Table 2. Lexicon for texture attributes of poultry breast meat

Attribute	Definition	Reference	Intensity
Initial hardness	Force required to compress sample 1 time	Cream cheese	1.0
		Egg white	2.5
		American cheese	4.5
		Beef frank	5.5
Hardness of mass	Force required to bite through the chewed sample up to 12 times	Olive	7.0
		Peanut	9.5
		Almond	11.0
		Life savers	14.5
Cohesiveness of mass	Amount that the chewed sample up to 12 times holds together	Shoestring licorice	0.0
		Carrots	2.0
		Mushrooms	4.0
		Beef frank	7.5
		American cheese	9.0
		Brownie	13.0
		Dough	15.0
Number of chews	Number of chews just before swallowing		

effects and panelist and panelist × deboning time interaction (if existing) as random effects. The interaction was served as the error mean square in the denominator of the F-statistics for testing fixed effect variations (i.e., deboning time; Lundahl and McDaniel 1988). Means were separated using least squares means with a PDIFF option in PROC MIXED at a significance level of 0.05.

Because all air deformation system parameters were extracted from a single curve, collinearity between these parameters was of concern. Therefore, predicted models for sensory attributes and instrumental parameters (MORSE and BMORSE) were established using both ordinary least squares (**OLS**) regression and partial least squares (**PLS**) regression (JMP version 5.1.2., SAS Institute Inc.). Partial least squares regression has an advantage over OLS regression in solving multicollinearity among independent variables where they were highly correlated to each other.

Individual fillets were classified into a tender or tough category using the instrumental data. Xiong et al. (2006) established, by correlating broiler breast meat tenderness perception and its corresponding values from instrumental parameters, that the MORSE value that distinguished tender and tough fillets was 150 N × mm. The hardness of 6 was calculated as a distinction value between tender and tough fillets based on the MORSE of 150 N × mm, and the boundary for BMORSE was calculated to be 165 N × mm based on the hardness of 6 calculated.

To test the validity or power of the models established for the classification of meat into tenderness categories, predicted values obtained from the models and observed values of individual fillets were subjected to logistic regression. Logistic regression is used when dependent variables are both dichotomies and categories. The dependent variables were assigned to true when both predicted values obtained from the models and observed values of individual fillets were in the same tenderness category, and they were assigned to false when different.

To estimate a model performance (model robustness or stability), all data were subjected to PLS1 regression using statistical software (Unscrambler version 9.2, CAMO, Trondheim, Norway). The following statistics were reported: the coefficient of determination for calibration (R^2_{cal}) and validation , root mean square error of calibration and root mean square error of prediction (**RMSEP**), the ratio of root mean square error of calibration and RMSEP (robustness), and discrimination index, all of which are typical assessors that have been reported as model performance indicators (Sitakalin and Meullenet, 2000; Sesmat and Meullenet, 2001). Both predictive variables (parameters from air puff and shape profile method) and responses (hardness, MORSE, and BMORSE) were standardized by weighing with the standard deviation to ensure that predictive variables have the same probability to influence the estimation of responses. This allows a change of one predictive variable to be approximately equal to that of another predictive variable. The full cross-validation was employed, meaning that each observation was in turn taken out of the calibration data set, and a model with the remaining data set was established. The process was repeated until every observation was removed once. An uncertainty test was also employed, which is normally used to optimize the predicted models testing the significance or lack of significance of the model parameters and is performed during the process of cross-validation (Meullenet et al., 2002).

RESULTS AND DISCUSSION

Sensory and Instrumental Analysis

The mean values of the sensory and instrumental measurements of fillets subjected to all deboning treatments are provided in Table 3. As expected from earlier studies (Lyon and Lyon, 1990; Cavitt et al., 2004, 2005), all sensory attributes, MORS, and BMORS measurements indicated, with increasing values, that early deboned fillets (1.25 h PM) were tougher than late-deboned fillets (24 h PM). Air puff parameter area difference up to maximum peak and maximum peak difference both increased with PM deboning times, indicating that the amount of deformation on the surface of raw fillets due to the pressurized air was negatively correlated to tenderness and that more deformation occurred by pressurized air on tender meat.

Table 3. Sensory and instrumental mean scores of fillets by different postmortem (PM) deboning time[1]

Parameter	PM deboning time (h) 1.25	4	24
Sensory attributes			
Initial hardness	6.6^{a}	5.5^{b}	5.2^{b}
Hardness of mass	6.2^{a}	5.7^{ab}	5.5^{b}
Cohesiveness of mass	6.1^{a}	5.2^{b}	4.9^{b}
Number of chews	23.3^{a}	20.4^{ab}	19.7^{b}
MORS measurements			
MORSF[2]	13.0^{a}	10.1^{b}	8.7^{c}
MORSE[2]	169.8^{a}	132.3^{b}	120.8^{c}
BMORSF[3]	17.3^{a}	12.1^{b}	10.2^{c}
BMORSE[3]	207.0^{a}	152.9^{b}	134.6^{c}
Air deformation measurements			
ADM[4]	42.2^{b}	45.9^{ab}	48.6^{a}
MPD[4]	2.2^{b}	2.6^{ab}	3.2^{a}

[a–c]Means with different letters in the same row are significantly different (α = 0.05).

[1]Only significant parameters were presented.

[2]MORS force (N) and MORS energy (N × mm) from the Meullenet-Owens razor shear.

[3]BMORS force (N) and BMORS energy (N × mm) from the Blunt-Meullenet-Owens razor shear.

[4]ADM = area difference up to maximum peak between 2 profiles; MPD = maximum peak difference of 2 profiles.

The other parameters from the air deformation system, total area difference, area difference above a height of 15 mm, and the area difference above a height of 20 mm, were not discriminators for the fillets deboned at different PM deboning times.

Classification into Tender and Tough Meat by Predicted Models

Individual fillets were classified into tenderness levels by models established with the air puff and shape profile method (Table 4). All the established models were highly significant ($P < 0.0001$).

Because a large number of samples are of necessity for robust regression models as well as reliable classification rates, fillets were modeled and classified by tenderness levels across all the deboning times (i.e., 1.25, 4, and 24 h PM). As discussed earlier, the classification into tender and tough categories was performed using the instrumental-sensory tenderness perception correspondence scales obtained from the study of Xiong et al. (2006), although the scales might not be completely representative in this case due to the potential variability in consumer perception or samples employed by different research. However, it was thought that the variability could be minor, because in the study of Xiong et al. (2006), a relatively large num-

Table 4. Classification for tender and tough meat by predicted models and improvements in tenderness after classification[1]

Parameter	Hardness OLS	Hardness PLS	MORSE OLS	MORSE PLS	BMORSE OLS	BMORSE PLS
F1: Observed = tender and predicted = tough	11	12	7	13	7	29
T1: Observed = tender and predicted = tender	63	62	63	57	60	38
T2: Observed = tough and predicted = tough	22	22	25	22	29	38
F2: Observed = tough and predicted = tender	14	14	15	18	14	5
Rate of overall correct classification[2] (%)	77	76	80	72	81	69
Rate of correct classification for tough meat[3] (%)	61	61	63	55	67	88
Rate of correct classification for tender meat[4] (%)	85	84	90	81	90	57
Tender meat before classification[5] (%)	67	67	64	64	61	61
Tender meat in tender stream after classification[6] (%)	82	82	81	76	81	88
Improvements in tenderness after classification[7] (%)	22	21	27	19	33	45

[1]Total number of observation (individual fillets) = 110. MORSE = Meullenet-Owens razor shear energy (N × mm); BMORSE = Blunt-Meullenet-Owens razor shear energy (N × mm). Hardness = tender ≤6, tough >6; MORSE = tender ≤150 (N × mm), tough >150 (N × mm); BMORSE = tender ≤165 (N × mm), tough >165 (N × mm). OLS = ordinary least squares regression; PLS = partial least squares regression.

[2]$[(T1 + T2)/110] \times 100$.

[3]$[T2/(T2 + F2)] \times 100$.

[4]$[T1/(F1 + T1)] \times 100$.

[5]$[(F1 + T1)/110] \times 100$.

[6]$[T1/(T1 + F2)] \times 100$.

[7]Calculated based on tender fillets before and after classification.

Table 5. Model statistics by partial least squares regression for the prediction of meat tenderness from the air deformation system[1]

Parameter	PC	R^2_{cal}	R^2_{val}	RMSEC	RMSEP	Robustness	SD	RPD
Hardness	7	0.46	0.40	1.17	1.24	1.06	1.60	1.29
MORSE	2	0.27	0.18	27.20	29.20	1.07	31.99	1.10
BMORSE	2	0.27	0.18	39.90	42.90	1.08	47.06	1.10

[1]PC = optimal number of principal components; R^2_{cal} = calibration coefficient of determination; R^2_{val} = validation coefficient of determination; RMSEC = root mean square error of calibration; RMSEP = root mean square error of prediction; robustness = RMSEP/RMSEC; SD = SD of all fillets across all postmortem deboning time; RPD = discrimination index (SD/RMSEP). MORSE = MORS energy (N × mm) from the Meullenet-Owens razor shear; BMORSE = BMORS energy (N × mm) from the Blunt-Meullenet-Owens razor shear.

ber of samples (1,008 fillets) deboned at various PM deboning times with the range of times used in the present study were used to establish the scales using a 74-member consumer panel.

The accuracy of models established from the air puff system was first assessed by a rate of correct classification into tender and tough fillets. It was observed that OLS regression tended to provide higher correct classification rates than PLS regression for all the predicted parameters (hardness, MORSE, and BMORSE), which was expected. The goal of OLS regression is to minimize the errors from predicted models under the assumption of linear functions between response variables and independent variables, whereas PLS regression works by extracting successive orthogonal linear combinations of the predictors that better explain the variations in the predictors.

The highest rate of overall correct classification was observed for BMORSE predicted by OLS regression with the rate of 81%, whereas the lowest rate was also found for BMORSE predicted by PLS regression with the rate of 69% (Table 4). The rate of correct tender fillet classification ranged from 81 to 90% except for BMORSE by PLS regression (57%). Conversely, observed tough fillets were correctly classified as tough with a range of 55 to 67% accuracy of classification except for BMORSE by PLS regression (88%). Consequently, the air puff system seemed to be better capable of identifying tender than tough meat. This might be due to the fact that the air pressure of 206.8 kPa applied to fillets was too low to cause sufficient deformations occurring on the surface of tough fillets. However, the most important measure of efficacy of an online tenderness classification system is to compare the proportion of tender fillets in the original stream to that in the stream identified by the laser air puff system as being tender.

Before classification, the rate of tender fillets ranged between 61 and 67% depending on the measure of tenderness. After classification, the rate of tender fillets in the air puff tender stream ranged from 76 to 88%. This represents an improvement in the rate of tender product identification, from 19 to 45%. This could be a considerable increase in the number of tender fillets that can be classified as such by using the air puff system at line speed. However, 83% accuracy may not be great enough to allow a claim of guaranteed tender broiler breast meat.

Modeling statistics for predicting hardness, MORSE, and BMORSE by PLS regression were examined (Table 5). As summarized in Table 5, although responses (hardness, MORSE, and BMORSE) were marginally fitted by predicted variables with a range of R^2_{cal} of 0.27 to 0.46, their relative errors of prediction were lower than the standard deviations of responses across all fillets. Furthermore, the validation coefficient of determinations for the responses (coefficient of determination for validation = 0.18 to 0.40) were similar to those of the calibration (R^2_{cal} = 0.27 to 0.46), resulting in robustness very close to 1. This indicates that these were all robust models. A large RMSEP value was unexpectedly observed for both MORSE and BMORSE models. Because only half of each fillet was used for the MORS and BMORS analyses in the present study, 2 measurements per fillet for each instrumental method were taken and averaged to estimate the tenderness of an entire fillet's tenderness, possibly producing means unrepresentative of the true tenderness level. In fact, Lee et al. (2007) reported that 5 measurements per fillet for MORS were recommended for a reliable estimate of the tenderness of a broiler breast fillet. The MORSE had a lower RMSEP than BMORSE, suggesting that more accurate prediction was obtained by the MORSE model. Even though discrimination index values greater than 2.0 have been reported to be discriminative (Meullenet et al., 2004), a hardness model was found to be more discriminative than instrumental parameters such as MORSE and BMORSE. The large RMSEP of the predictive models could be attributed to external factors such as incomplete laser reflectance. Even though every fillet was covered with a white plastic film, some red color may have absorbed some amounts of the laser beam, which could possibly have been influenced by conveyor belt speed. Future studies should investigate optimal conveyor belt speed to optimize laser sensor performance or more sophisticated sensors.

Overall, a hardness model seemed to be superior to the instrumental models when considering all model statistics (Table 5), especially the lower RMSEP. However, broiler breast meat tenderness was still relatively well-predicted by the air deformation system in terms of classifying breast meat into tenderness levels with a high accuracy, especially for tender meat.

Although the overall correct classification rate for a tender and tough fillet obtained using the combined shape profile and air puff methods was not completely satisfactory (i.e., both methods had in average 83% accuracy), we believe the system could be improved. It is expected that the accuracy of the system could be improved after resolving a few technical issues including laser light absorption by the fillets and the need for optimization of conveyor belt speed and applied air pressure.

In conclusion, the laser air deformation system seemed to have potential for implementation as an online tool for sorting broiler breast fillets by tenderness levels. This new system shows potential as a nondestructive method, providing a means of identifying early deboned, naturally tender, nonmarinated broiler breast meat, which may ultimately retail at a slight premium. Because it was observed that this system had a better ability to identify tender than tough meat, further investigations should include improving the accuracy of the classification rate of tough meat. Moreover, laser absorption into fillets should be resolved by testing different types of sensors that are not affected by the color of objects. For example, acoustic sensors with an ultrasound wave could be good candidates as an alternative to laser sensing.

REFERENCES

Banner Engineering Corp. 2007. Application considerations for L-Gage sensors. http://stevenengineering.com/Tech_Support/PDFs/04LGAGE.PDF Accessed June. 1 2007.

Cavitt, L. C., J. F. Meullenet, R. Xiong, and C. M. Owens. 2005. The relationship of razor blade shear, Allo-Kramer shear, Warner-Bratzler shear and sensory tests to changes in tenderness of broiler breast fillets. J. Muscle Foods 16:223–242.

Cavitt, L. C., and A. R. Sams. 2003. The evaluation of physical dimension changes as non-destructive measurements for monitoring rigor mortis development in broiler muscles. Poult. Sci. 82:1198–1204.

Cavitt, L. C., G. W. Youm, J. F. Meullenet, C. M. Owens, and R. Xiong. 2004. Prediction of poultry meat tenderness using Razor Blade shear, Allo-Kramer shear, and sarcomere length. J. Food Sci. 69:S11–S15.

Hamm, D. 1981. Unconventional meat harvesting. Poult. Sci. 60 (Suppl. 1): 1666. (Abstr.)

James, S. J. 2002. New developments in the chilling and freezing of meat. Pages 298–312 in Meat Processing – Improving Quality. J. Kerry and D. Ledward, ed. Woodhead Publ., Boca Raton, FL.

Jones, J. M., and T. C. Grey. 1989. Influence of processing on product quality and yield. Pages 127–181 in Processing of Poultry. G. C. Mead, ed. Elsevier, New York, NY.

Lee, Y. S., A. Saha, C. M. Owens, and J. F. Meullenet. 2007. Optimal number of replications for the Meullenet-Owens-Razor-Shear (MORS) and tenderness variations between right and left broiler breast fillets. Poult. Sci. 86(Suppl. 1):378. (Abstr.)

Lundahl, D. S., and M. R. McDaniel. 1988. The panelist effect – fixed or random? J. Sens. Stud. 3:113–121.

Lyon, B. G., and C. E. Lyon. 1990. Texture profile of broiler pectoralis major as influenced by post-mortem deboning time and heat method. Poult. Sci. 69:329–340.

McGlone, V. A., S. M. W. Ko, and R. B. Jordan. 1999. Non-contact fruit firmness measurement by the laser air-puff method. Trans. ASAE 42:1391–1397.

Meullenet, J. F., M. L. Finney, and M. Gaud. 2002. Measurement of biting velocities, and predetermined and individual cross-head speed instrumental imitative tests for predicting cheese hardness. J. Texture Stud. 33:45–58.

Meullenet, J. F., E. Jonville, D. Grezes, and C. M. Owens. 2004. Prediction of the texture of cooked poultry pectoralis major muscles by near-infrared reflectance analysis of raw meat. J. Texture Stud. 35:573–585.

Meullenet, J. F., R. Xiong, A. Saha, and C. M. Owens. 2005. Novel shape profiling method for classifying tender and tough broiler breast meat. Abstract 97-2 in 2005 IFT Annual Meeting Book of Abstracts, New Orleans. IFT, New Orelans, LA.

Prussia, S. E., and Y. C. Hung. 2001. Pages 151–155 in Improved Laser-Puff Food Firmness Detector. ISHS, Leuven, Belgium.

Prussia, S. E., Y. Hung, and J. J. Astleford. 1993. A non-contact firmness sensor. ASAE Paper No. 93–6538. ASAE, St. Joseph, MI.

Sesmat, A., and J. F. Meullenet. 2001. Prediction of rice sensory texture attributes from a single compression test, multivariate regression, and a stepwise model optimization method. J. Food Sci. 66:124–131.

Sitakalin, C., and J. F. Meullenet. 2000. Prediction of cooked rice texture using extrusion and compression tests in conjunction with spectral stress strain analysis. Cereal Chem. 77:501–506.

Xiong, R., L. C. Cavitt, J. F. Meullenet, and C. M. Owens. 2006. Comparison of Allo-Kramer, Warner-Bratzler and razor blade shears for predicting sensory tenderness of broiler breast meat. J. Texture Stud. 37:179–199.