Physical and Functional Properties of Intact and Ground Pale Broiler Breast Meat

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ABSTRACT The functional and physical properties of intact and ground meat were determined during 4 replicate trials on a total of 180 pale [lightness (L*) > 53] and normal (46 < L* < 53) boneless, skinless breast fillets collected from 2 commercial processing plants. At 24 h postmortem, L*, redness (a*), yellowness (b*), and pH were determined on each fillet. The left fillet from each breast was ground and used to determine cook loss (CL) and Allo-Kramer (AK) shear on meat patties as well as moisture uptake (MU) and CL on meat slurries before and after adjustment to the normal meat pH of 5.9. The right fillet from each breast was kept intact and used to determine expressible moisture (EM), CL, and AK shear on the intact meat. Compared with normal fillets, pale fillets exhibited significantly higher L* values, lower ultimate pH (5.67 vs. 5.94), higher AK (3.5 vs. 2.9 kg/g), higher EM, lower MU, and higher CL measured on the intact fillets, ground meat patties, and meat slurries. Adjustment of the pH of the pale meat slurries to normal meat pH (5.9) resulted in a higher MU (11.05 vs. 3.69%), indicating a partial restoration of protein functionality. These results indicate that wide differences in raw broiler breast meat color, mainly due to differences in the muscle pH, are related to important variations in the water-holding and binding capacities of the meat. The effect of low meat pH can be partially ameliorated in ground meat by pH adjustment.

(*Key words*: breast meat pH, broiler breast meat, functional property, pale breast meat)

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INTRODUCTION

The major poultry meat quality attributes are appearance, texture, juiciness, flavor, and functionality (Fletcher, 2002). With increasing trends in further processing, meat functionality has increased in relative importance, especially because of its key role in determining the sensory quality of complex ready-to-eat products. Water-holding capacity (WHC) and water-binding capacity of meat are also critical attributes for successful product formulation and process control.

Traditionally, less consideration has been given to the functional properties of poultry meat such as WHC and texture (Barbut, 1998). Loss in functionality of poultry breast meat is often associated with pale meat and is often referred to as pale, soft, exudative (PSE)-like in order to stress the similarity with the PSE syndrome in porcine muscle that is well documented in meat science literature. PSE-like poultry meat has been of interest in recent years due to several reports estimating that the pale meat can range from 5 to 30%, depending on flock, season, and factors affecting transportation. Boulianne and King (1995) reported that pale chicken breast meat observed in commercial processing plants and retail stores was described as "light white-yellow discolored breast meat turning to a pale gray discoloration during sorting and distribution, with no evidence of excessive microbial growth." An additional defect of pale meat occurs when it is used in further processing and causes a condition called "cracking" in which gaps appear inside the structure of the cooked meat (Sams, 1999). Pale poultry meat can be used in those products for which the functionality of the meat is not a primary issue or into formulations containing ingredients or processing conditions to restore protein functionality, WHC, and texture (Owens et al., 2000). A number of researchers have recently suggested the possibility of using color measurements to predict functional properties, specifically PSE-like conditions and WHC are the most common functional properties mentioned (Barbut, 1993, 1996, 1997a,b; Fletcher et al., 2000; Wilkins et al., 2000; Qiao et al., 2001, 2002b). Some researches have also indicated lightness (L*) values to be useful as an indicator of poultry breast meat quality for

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Abbreviation Key: AK = Allo-Kramer; CL = cook loss; EM = expressible moisture; L* = lightness; MU = moisture uptake; PSE = pale, soft, exudative; WHC = water-holding capacity.

further processing (McCurdy et al., 1996; Barbut, 1998; Owens et al., 2000; Woelfel et al., 2002). Woelfel et al. (2002) examined the incidence of PSE chicken meat in a commercial plant and reported that approximately 47% of the 3,554 fillets could potentially exhibit poor WHC. However, due to variations in color measurement it has also been suggested that each plant may have to determine its own L* values for sorting PSE meat depending on type of birds, processing factors, and final product specifications (Wilkins et al., 2000). Petracci et al. (2004) determined breast meat lightness on nearly 7,000 breast fillets from a single plant and reported significantly lighter fillets in the summer months.

A number of factors that affect the color values of breast meat have been reported. Petracci and Fletcher (2002) reported that color values are affected by early aging times during processing and during storage. Meat thickness (Sandusky and Heath, 1996; Bianchi and Fletcher, 2002) as well as the color measurement position on the fillet (Goshaw et al., 2000) have also been shown to affect meat color measurement.

Several researchers have examined the differences in meat characteristics of normal and pale fillets selected visually or using objective L* measurements from the deboning lines of commercial processing plants. However, differences exist between studies in the L* values adopted for identifying pale breast meat. Boulianne and King (1995) collected 600 fillets (300 normal and 300 pale) according to visual assessment, and the resulting L* values were 52.3 for the normal and 59.2 for the pale group. In another study, dark and pale fillets were selected based on visual score during 3 different trips to a commercial processing plant. The L* values for the dark and pale fillets for the 3 replicate trials were 43.7 vs. 51.6, 48.5 vs. 53.4, and 43.2 vs. 49.6 (Allen et al., 1997). Fletcher (1999) used plant personnel for selecting breast fillets based on their appearance as being "darker than normal," "normal," and "lighter than normal" and found L* values of 43.1, 45.6, and 48.8 for the 3 color groups, respectively. Van Laack et al. (2000) collected normal and pale chicken breasts based upon visual evaluation of color by plant personnel and reported L* values of 55.1 and 60.0 for the normal and pale fillets, respectively. Woelfel and Sams (2001) collected 335 broiler breast fillets (160 normal and 175 pale) according to visual assessment and L* values were found to be 52.4 for the normal and 60.3 for the pale group.

Although the relationship between pale breast meat, low pH, and loss of functionality are well established, there are considerable variations in the range of colors associated with pale meat in unselected breast meat populations. The purpose of this project was to study some functional and physical properties of intact and ground pale broiler breast fillets including an assessment of how much raw meat paleness affects functional properties of whole and processed meats.

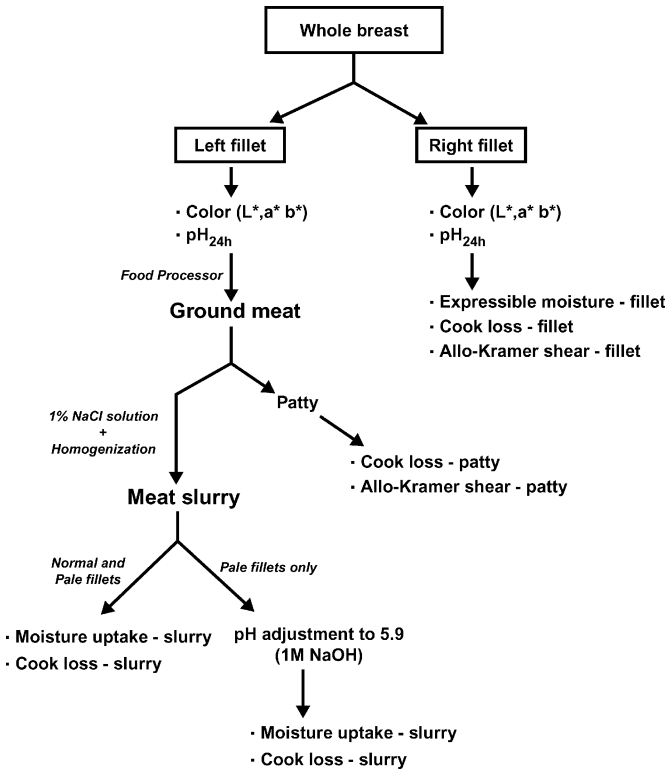

FIGURE 1. Experimental design to compare the whole breast fillet, ground meat patty, and meat slurry quality indices of color, pH, expressible moisture, cook loss, Allo-Kramer shear, and moisture uptake of pale and normal broiler breast meat. L* = lightness; a* = redness; b* = yellowness.

MATERIAL AND METHODS

Experimental Design and Methods

In 4 replicate trials conducted over 2 mo, a total of 50 normal and 40 pale boneless, skinless, 24 h postmortem whole breast fillets (butterflies with right and left lobes) were collected from the deboning lines of 2 commercial processing plants located in the southeastern United States. Breast fillets were first sorted visually to group by approximate L* and to obtain defect-free samples only. Final fillet selection was made by determining the L* values with a reflectance colorimeter while still in the plant. The fillets were selected based on normal fillets having L* values between 46 and 53 and pale fillets having an L* value greater than 53. Color was measured on the cranial, medial surface (bone side) in an area free of obvious color defects. Samples were subsequently placed in polyethylene bags by color group, packed on ice, and transported to the laboratory.

The experimental design, sampling scheme, and measurements are illustrated in Figure 1. The 2 fillets of each breast were separated, trimmed of excess fat and connective tissue, and placed on a white background to measure color. Color was determined using the CIELAB (CIE, 1976) color values for L*, redness (a*), and yellowness

(b*) using a portable reflectance colorimeter[2] and using illuminant source C. All calibrations and color readings were taken using the colorimeter-supplied optically inactive glass aperture cover to ensure a consistently flat sample surface. This cover was cleaned between each sample reading. The overall breast fillet color was evaluated averaging 3 color measurements from cranial to caudal medial (bone side) surface, in an area free of obvious color defects, bruises, blood spots, or surface discolorations caused by possible overscalding.

The breast fillet pH was measured on the distal cranial section of each fillet. The pH of each breast fillet was determined in duplicate using a modification of the iodoacetate method initially described by Jeacocke (1977). Approximately 2.5 g of breast meat was removed from the cranial end of each fillet, minced by hand, and homogenized in 25 mL of a 5 m*M* iodoacetate solution with 150 m*M* of potassium chloride for 30 s, and the pH of the homogenate was determined using a pH meter[3] calibrated at pH 4.0 and 7.0.

After color and pH, the right fillet was used to determine expressible moisture (EM), fillet cook loss (CL), and Allo-Kramer (AK) shear of the intact meat. The EM was determined using the Grau-Hamm filter paper press procedure (Grau and Hamm, 1956) as modified by Hoffman et al. (1982). Meat slices of 300 ± 5 mg were removed from the cranial end of the fillet and placed on a preweighed filter paper.[4] The paper with the meat slice was placed between 2 plexiglass plates, and a load of 1 kg was applied for 5 min. The filter paper was rapidly weighed after removing the compressed meat. Duplicate samples were averaged for each fillet. EM is expressed as follows: EM (%) = [(damp paper weight − dry paper weight) / (meat sample weight)] × 100.

The CL of intact fillets were determined by weighing the fillets and then cooking in a convection oven on aluminum trays at 150°C to an endpoint temperature of 80°C. The fillets were drained, allowed to equilibrate to room temperature, and weighed. CL is determined as a percentage of weight lost during cooking [(raw weight − cooked weight) / raw weight) × 100).

Shear values were determined using an Instron Universal Testing Machine[5] equipped with an AK shear cell using the procedure described by Papinaho and Fletcher (1996). A 25-mm diameter core was removed from the thickest part of each fillet and weighed, and the sample was sheared with the blades at a right angle to the fibers using a 500-kg load cell and cross-head speed of 500 mm/min. AK shear values are reported as kilograms shear per gram of sample.

The left fillet of each breast was then ground for a constant time using a food processor. The ground meat was divided to make patties to determine CL and AK shear or was used to make meat slurries to determine moisture uptake (MU) and CL of unadjusted normal and pale meat and pH adjusted pale meat. Meat patties were made from 70 g of ground meat and formed into patties that were 8.5 cm in diameter and 1.5 cm thick patties.

The CL of the patties was determined by weighing the raw patty and then cooking on aluminum trays in a convection oven at 150°C to an end point of 80°C. After draining and equilibration to room temperature, the patties were reweighed, and CL was determined as the percentage of weight lost. The AK shears of the patties were determined using an Instron Universal Testing Machine[5] equipped with an AK shear cell. A 25-mm diameter core sample was removed from the center of the cooked patty, and the sample was sheared using a 500-kg load cell and cross-head speed of 500 mm/min. AK shear values are reported as kilograms shear per gram of sample.

Moisture uptake and CL were determined on each ground breast fillet sample using a modification of the procedure proposed by Van Laack et al. (2000). This modification was used to allow easier pH modification of the ground meat. Exactly 30.0 g of ground meat was homogenized with 90 mL of a 1% NaCl solution by using a homogenizer[6] at 9,500 rpm for 60 s. The pH of the meat slurry was determined directly, and 20.0 g of the slurry was centrifuged at 22,000 × *g* for 10 min at 6 to 8°C. The supernatant was discarded, the tube was thoroughly drained, and the weight of the pellet was determined. The MU was calculated as follows: MU (%) = [(weight of pellet − weight of meat) / (weight of meat)] × 100, where weight of pellet = (weight of tube + pellet) − weight of tube; and weight of meat = weight of the slurry (20 g) × 2.5 (slurry = 25% meat and 75% NaCl solution).

The tubes were subsequently heated at 80°C for 20 min on a water bath. After incubation, the released water was discarded, and the tubes were allowed to equilibrate to room temperature and reweighed for CL (CL) determination as follows: CL (%) = 100 − [(weight of cooked pellet) / (weight of meat)] × 100.

The slurries from the pale fillets were transferred into a beaker, and the pH was adjusted to 5.90 ± 0.01 with 1M NaOH (the normal fillets had an average pH of 5.9). The pale meat slurry had initial pH values lower than 5.90. After pH modification, the MU and cooking yield determinations were carried out as previously described and taking into account the amount of basic solution added to the meat slurry in order to determine the weight of the meat.

Statistical Analyses

Data were analyzed using the ANOVA option of the GLM procedure of SAS (SAS Institute, 1988). The model tested both the main effects for color group and replication as well as the interaction term using residual error. When the color group by replication interaction was significant ($P < 0.05$), the interaction mean square error was used to determine the significance of the main effects

[2]Minolta Chroma Meter CR-300, Minolta Corp., Ramsey, NJ.
[3]Sentron Model 2001 with a model 1000 probe, Sentron Inc., Federal Way, WA.
[4]Whatman No. 1 (No. 1001 110), Whatman Inc., Clifton, NJ.
[5]Instron Corp., Canton, MA.
[6]Ultra-Turrax T25, IKA Works Inc., Wilmington, NC.

TABLE 1. Means and standard error of the means for breast meat lightness (L*), redness (a*), yellowness (b*), pH, expressible moisture, cook loss, Allo-Kramer shear, and moisture uptake of whole fillets, patties, or meat slurries from normal and pale broiler breast fillets

Parameter	Normal	Pale	Pale, pH adjusted[1]	*P*
L*	50.9 ± 0.2	58.9 ± 0.3	—	<0.0001[2]
a*	3.8 ± 0.1	2.6 ± 0.1	—	<0.0001[2]
b*	6.2 ± 0.2	7.6 ± 0.2	—	NS*[2]
pH	5.94 ± 0.01	5.67 ± 0.01	—	0.0001[2]
Expressible moisture (%), fillet	23.5 ± 0.4	26.3 ± 0.4	—	<0.0001[3]
Cook loss (%), fillet	23.3 ± 0.4	26.6 ± 0.5	—	<0.0001[3]
Allo-Kramer shear (kg/g), fillet	2.9 ± 0.2	3.5 ± 0.3	—	0.0072[3]
Cook loss (%), patty	22.2 ± 0.5	25.6 ± 0.7	—	<0.0001[3]
Allo-Kramer shear (kg/g), patty	4.0 ± 0.2	3.2 ± 0.1	—	NS*[3]
Moisture uptake (%), slurry	23.1[a] ± 1.4	3.7[c] ± 1.2	11.1[b] ± 1.2	<0.0001[3]
Cook loss (%), slurry	11.8[b] ± 1.2	24.7[a] ± 0.6	20.1[a] ± 1.0	0.0169*[3]

[a–c]Means within a column and parameter with different superscripts are significantly different.

[1]pH of the meat slurries adjusted to 5.90 with 1 *M* NaOH.

[2]n = 180 (normal, 100; pale, 80).

[3]n = 90 (normal, 50; pale, 40).

*Significant group-by-replicate interaction. Significance was determined using group-by-replicate mean square error as the test statistic.

(SAS Institute, 1988). Means were separated using the Duncan's multiple range test option and the model error term as previously described. Pearson's correlation coefficients (r), regression model (R^2), and probabilities were generated using the correlation procedures of SAS (SAS Institute, 1988).

RESULTS AND DISCUSSION

The physical and functional properties of normal, pale, and pale pH adjusted broiler breast fillets and ground meat are presented in Table 1. Samples were selected in color groups based on L* values; normal fillets had L* values between 46 and 53 and averaged 50.9, and pale fillets selected had L* values above 53 and averaged 58.9. Thus, the highly significant differences between color groups were expected. The significant L* and redness results were consistent with previous studies that reported the pale meat as having lower redness than normal and dark meat (Boulianne and King, 1995; Allen et al., 1997; Fletcher, 1999; Van Laack et al., 2000; Qiao et al., 2001). There was a significant group-by-replicate interaction for yellowness, which, when tested using the interaction mean square error, resulted in no significant difference between the normal and pale meat. The lack of difference in yellowness values in samples with widely different L* values is not uncommon (Fletcher, 1999; Fletcher et al., 2000; Van Laack et al., 2000).

The pH for the normal fillets was 5.94, which was significantly ($P < 0.0001$) greater than the pH for the pale fillets (Table 1). The significant pH difference between the normal and pale fillets was consistent with numerous previously reported data. The difference of 0.26 pH units was very similar to the results reported by Van Laack et al. (2000) in which normal fillets have a pH of 5.96, and pale fillets have a pH of 5.70.

For the whole fillets, the normal meat exhibited significantly lower EM, CL, and AK shear than the pale fillets (Table 1). The lower EM (equivalent to greater WHC) and CL values were consistent with the higher pH values of the normal meat. Although the shear values were significantly different, 2.9 vs. 3.5 for the normal and pale fillets, respectively, both were in the shear value ranges consistent with acceptably tender meat.

Cook loss results for the ground meat patties were similar to those for the intact fillets. The patties from the ground normal meat had a CL of 22.2%, which was significantly less than the CL of 25.6 for the patties from the ground pale meat. There was no difference between the 2 meat sources for ground meat shear.

The results for MU and CL for the meat slurries made from the normal, pale, and pH adjusted pale meat are shown in Table 1. MU was significantly greatest for the normal meat slurries (23.1%) followed by the pH adjusted pale meat (11.1%), both of which were greater than the pale meat MU (3.7%). CL was significantly greatest for the pale and pH adjusted pale meat (24.7 and 20.1%, respectively), which were not different from each other, compared with the CL of 11.8% for the normal meat slurry.

The results for the pale meat with the greater intact fillet EM, lower slurry MU, and consistently greater CL for intact fillets, patties, and slurries were consistent with previous published reports and indicate that extremely pale fillets have poor characteristics for further processing relative to water binding and cooked meat yields. Van Laack et al. (2000) concluded that the ultimate pH of pale fillets appeared to be the main determinant for the low WHC, and procedures for increasing pH of pale meat to that of normal meat were expected to be useful in improving meat functionality. These results indicate that adjustment of the pH of pale meat slurries to that of normal color pH resulted in a significantly higher MU, indicating partial restoration of protein functionality. Woelfel and Sams (2001) reported that marination in salt and alkaline phosphate solution at pH 9 improved the

TABLE 2. Regression coefficients[1] (regression model R^2, probability, intercept, and slope), and probabilities for breast meat lightness (L*), pH, and other quality traits

Dependent variable (y)	Independent variable (x)	n	R^2	Prob.	Intercept (b)	Slope (m)
pH	L*	180	0.70	0.0001	7.49	–0.03
Expressible moisture, fillet	L*	90	0.26	0.0001	6.49	0.33
Cook loss, fillet	L*	90	0.32	0.0001	1.35	0.43
Cook loss, patty	L*	90	0.13	0.001	5.73	0.33
Cook loss, slurry	L*	90	0.51	0.0001	–58.42	1.40
Allo-Kramer, fillet	L*	90	0.05	0.038	–1.27	0.08
Allo-Kramer, patty	L*	90	0.28	0.0001	9.91	–0.11
Moisture uptake, slurry	L*	90	0.63	0.0001	135.43	–2.22
Expressible moisture, fillet	pH	90	0.25	0.0001	77.58	–9.09
Cook loss, fillet	pH	90	0.23	0.0001	82.45	–9.92
Cook loss, patty	pH	90	0.35	0.0001	97.24	–12.90
Cook loss, slurry	pH	90	0.58	0.0001	–216.70	34.96
Allo-Kramer, fillet	pH	90	0.06	0.024	17.15	–2.41
Allo-Kramer, patty	pH	90	0.28	0.0001	–11.74	2.70
Moisture uptake, slurry	pH	90	0.79	0.0001	–316.94	58.18

[1]For example, y = mx +b (pH = –0.03 L* + 7.49; L* = –22.95 pH + 188.07).

WHC and partially restored protein functionality of pale broiler breast fillets.

The inconsistent results for the shear value between the intact fillets and patties are not unexpected. In a previous experiment comparing breast meat samples of different color categories, no difference in texture was found (Fletcher, 1999).

Regression analyses were conducted on the relationship between L*and pH as well as on the meat quality measurements to L* and pH. The regression coefficients (regression model R^2, probability of the slope not being equal to zero, intercept, and slope) are presented in Table 2. There was a highly significant negative linear relationship between L* and pH (model R^2 = .70). All of the meat quality parameters also had significant linear relationships with breast meat L*. The model R^2 values were very similar for the breast meat quality attributes as a function of lightness or pH (due to a strong autocorrelation between L* and pH). These results were consistent with previous studies documenting the relationships among broiler breast meat lightness, pH, and functional properties (Barbut, 1998; Fletcher et al., 2000; Van Laack et al., 2000; Wilkins et al., 2000; Qiao et al., 2002a,b; Woelfel et al., 2002). As a result, many of these authors have suggested color as a means of predicting potentially poor functional quality meat.

These results confirm the strong relationship among wide variations in breast meat color, muscle pH, and subsequent meat functionality. It also shows that pH modification can in part ameliorate some of the negative consequences of low pH meat in a meat slurry system.

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