PROTEIN FUNCTIONALITY AND SENSORY PROPERTY OF BROILER CARCASSES CHILLED BY WATER, AIR, OR EVAPORATIVE AIR

J. Y. Jeong[1], K. K. Janardhanan[1], A. M. Booren[1,2], J. B. Harte[2], and I. Kang[1,2*]

[1]Department of Animal Science, Michigan State University, East Lansing, MI 48824, United States

[2]Department of Food Science & Human Nutrition, Michigan State University, East Lansing, MI 48824, United States
[*]Corresponding author (phone: +1-517-355-8452, ext. 203; fax:+1-517-432-0753; e-mail: kangi@msu.edu)

***Abstract*——Three poultry chilling methods (water, air, and evaporative air) were compared to evaluate their effects on broiler breast's quality, textural property, and consumer sensory attribute. In temperature reduction, water chilling (WC) reduced carcass temperature most efficiently (57 min) while air chill (AC) and evaporative air chill (EAC) were the least (125 min) and middle (93 min), respectively. No significant difference was found among the chilling methods in moisture content, cooking yield, and shear force of skinless breast fillets stored overnight. However, the pH (5.63) of 24 h-stored fillets was higher in WC than AC (5.52) and EAC (5.49). In color, WC showed a higher CIE *L** value than AC or EAC while AC generated more red (higher CIE *a**) and yellow (higher CIE *b**) color than other two chilling methods. When breasts were made into gels, there was no significant difference in cooking loss, moisture content, shear stress, and shear strain, regardless of chilling methods. In sensory evaluations, air chilled breasts received a higher juiciness score than other two chilling. However, no significant difference was also found for the rest of sensory properties such as flavor, texture firmness, and overall acceptability.**

***Index Terms*— Air chilling, Broiler breasts, Evaporative air chilling, Water chilling.**

I. INTRODUCTION

Efficient and economical chilling is a major benefit of water chilling (WC) on poultry, and the United States has used the technology up to today. The advantage, however, has recentlly been challenged by many factors such as cross-contamination, waste-water management, re-shackling, and post-chill purge (McKee, 2001; Sanchez, Fluckey, Brashears & McKee, 2002; Durhan, 2008; Veerkamp, 1991). In Europe, air chilling (AC) has been commercialized for alomost 35 years since WC was banned in 1977 (Lillard, 1982). A primary reason for the ban was the potential of increasing of cross-contamination during chilling (Thomas, 1977). Evaporative air chilling (EAC) also was developed as an alternative method to AC with an improved heat transfer and reduced skin discoloration. Recently, several poultry processors in the United States adopted the AC technology and promoted air-chilled chickens with a premium, natural or organic brand. Different chilling mehtods have different results on moisture content, apperance, cooking loss, and product taste of broiler carcass (James, Vincent, de Andrade Lima & James, 2006; Huezo, Smith, Northcutt & Fletcher, 2007; Young and Smith, 2004). Having ideal texture and improved flavor, air chilled chicknes are reported to be prefered over the water immersed ones (Gazdziak, 2006; Veerkamp, 1991). There are some published data comparing the properties of air versus water chillig on meat qualities and sensory profiles in the United States (Huezo et al., 2007; McKee, 2001), but not many reserach have conducted for the comparion of three chilling mehtods (air, water, and evaporative air) on boriler carcass quality and sensory properties. Therefore, the objective of this study was to compare the effects of the three chilling methods on meat quality, textural properties, and consumer sensory attributes on broiler breasts.

II. MATERIALS AND METHODS

A. Broiler carcass preparation

A total of 189 male birds (approximately 46-d-old broiler; 63 birds/each replication) were obtained from a local broiler producer. After withdrawing from feed for 12 h, birds were transported to Michigan State University poultry processing facility. Upon arrival, birds were shackled, electrically stunned (110 V, 1 A for 2 sec) and killed by bleeding (severing the neck) for 90 sec. In each replication, 21 birds (for water chilling) were subjected to hard scalding at 56.7 °C (120 sec), and 42 birds to soft scalding at 50°C (220 sec) for either air or evaporative air chilling. The birds then were defeathered in a rotary drum picker for 25 sec, manually eviscerated and washed. After draining on shackle line for 5 min, each carcass was tagged on wing and assigned to one of 3 chilling treatments. Three separate replications were conducted in the same processing method.

B. Chilling treatments, deboning, and storage

In each replication, 21 carcasses from a hard scald were submersed for WC into ice/water slush (7.6 L/bird, 0 ± 0.4 °C) and manually agitated every 5 min in a chilling room at 1 °C. After chilling, each carcass was positioned to empty the water in cavity and shackled by hocks to allow additional drip for 5 min prior to weighing. For AC and EAC, 42 carcasses from a soft scald were randomly assigned to one of the air-mediated chilling, which received a continuous blowing-air (1.0 m/sec) in a chilling room. Air blowing was generated by an industrial-size fan (Model BF30DD, Ventamatic, Ltd., Mineral Wells, TX) that was installed for each of AC and EAC. For EAC, cold water (approximately 0.4 °C) was manually sprayed onto carcasses (0.5 L/carcass) every 5 min in addition to the air blowing. In each chilling, an extra carcass was used to monitor an internal breast temperature with a digital thermometer/logger probe (Model 800024, Sper Scientific, Ltd., Scottsdale, AZ) until the temperature reaches to 4 °C or below. Chilling room's temperature and relative humidity were recorded every 15 min. Upon completing of chilling, carcasses were unshackled, individually packaged in a freezer bag, and held for 5 h postmortem prior to deboning breasts. From the surface of skinless breasts, CIE $L^*a^*b^*$ values were measured (3 readings/each side) using a chroma meter (CR-400, 8 mm aperture, illuminant C; Minolta Corp., Osaka, Japan) that was calibrated with a white plate (L^* 97.28, a^* -0.23, b^* 2.43). After a color measurement, all breasts were individually placed in plastic bags and stored on ice for later analysis.

C. Observation methods and statistical analysis

For muscle pH and moisture values, anterior portions (25g) of 10 left breasts out of 20 broilers per treatment were taken after 24 h aging. The sample (5 g) was homogenized in 25 mL deionized water, and pH values were read with a pH electrode attached to a pH meter (Accumet AR50, Fisher Scientific, Pittsburgh, PA). Additional sample (3 g) was used for moisture content, in duplicate, following the method of AOAC (2002). For a protein gel preparation, the fillets without anterior portion were pooled (1,500 g meat, 68%), chopped with 15% ice in a bowl cutter at 1,500 rpm for 30 sec, and then emulsified at 2,100 rpm with additional 15% ice and 2% sodium chloride for 2.5 min to a final temperature < 5 °C. The meat batter was stuffed into pre-weighed stainless-cylindrical tubes, which were capped, weighed again (for later cook yield), and cooked in a water bath at 80 °C for 20 min. After cooking, the tubes were immediately cooled in ice for 15 min and stored overnight (2-3 °C) for later evaluation. Following day, cooked gels were removed and three parts (gels, empty-tubes and caps) were individually weighed for a cooking yield determination. Gels were inserted into plastic bags and saved in a refrigerated room. After setting in a room temperature for 3 h, the gels were cut into 3.0 cm, milled into a dumb-bell shape (10 mm at midsection) using a shaping machine, and placed on a Brookfield viscometer (Model DV-III Ultra, Brookfield Engineering Laboratories, Inc., Middleboro, MA). The resulting gels were twisted at 2.5 rpm and both shear stress and shear strain values were calculated from torque and elapsed time using equations given by Hamann (1983).

Other 10 left fillets out of 20 broilers per treatment were used for fresh muscle color (explained in *B* above), cooking yield and shear force. For cooking fillets, each breast was weighed and placed on stainless racks in stainless trays. After covering with aluminum foil, trays were inserted into a pre-heated convention oven (177 °C) and cooked to an internal temperature of fillets at 76.7 °C following USDA-FSIS guidelines (USDA-FSIS, 2001). The temperature was monitored using a digital thermometer/logger thermocouple (Model 800024, Sper Scientific, Ltd., Scottsdale, AZ) placed in the geometric center of the thickest breast part. The cooked filets were individually wrapped with aluminum foil and stored overnight (2-3 °C). Following day, cooked breasts were kept at room temperature for 2 h and weighed for a cooking yield. Shear force of the breasts was determined according to the Razor-blade method described by Cavitt, Youm, Meullenet, Owens and Xiong (2004) using a Texture Analyzer (Model TA-HD*i*, Texture Technologies Corp., Scarsdale, NY). Shear force value (N) was calculated as a maximum force when each fillet was sheared.

For consumer sensory evaluations, 20 right-side fillets/treatment were cooked following USDA-FSIS guidelines (USDA-FSIS, 2001). Immediately after cooking, each breast was cut into an approximately 5 × 6-cm portion, wrapped with aluminum foil, and kept in a warm container (maintained at 60 °C) until used. The prepared part, upon serving, was cut into 4 pieces (a total of 80 pieces/treatment) and labeled with a three digit number. Sensory evaluation was conducted by panelists in individually arranged testing booths under white lighting. A total of 210 consumer panelists (70/replication) were requested to evaluate each of three-chilled samples for flavor, texture, juiciness, and overall acceptability on a 9-point hedonic scale (9 = like extremely and 1 = dislike extremely). Filtered water and unsalted crackers were provided for mouth washing between samples. Resulting scores were punched into a computer by the panelist immediately after evaluations.

All experiments were replicated three times. Data were statistically analyzed using the general linear model (GLM) procedure of the statistical analysis system (SAS, 2002) as a randomized block design. If significance was determined ($p < 0.05$) in the model, dependent variable means were separated using the Least Significant Difference procedure of SAS. Consumer sensory evaluation data were pooled across panelists and were analyzed as previously described.

III. RESULTS AND DISCUSSION

During chilling, three chilling methods recuced broiler carcass temperature from 40.7 °C to 4 °C with the best (57 min) efficiency, intermedaite (93 min), and the least (125 min) by water chill (WC), evaporative air chill (EAC), and air chill (AC), respectively (Fig 1). The pH, moisture content, and cooking yield of broiler breasts, after chilling and 24 h storage, are shown in Table 1. Breasts of WC had higher ($p < 0.05$) pH values than those of AC or EAC which were not different ($p > 0.05$) each other. However, no significant difference ($p > 0.05$) was found for moisture content and cooking yield regardless of chilling methods.

When the surface color of deskined breasts were evaluated at 5 h postmortem, water chilled breasts showed the highest ($p < 0.05$) CIE L^* value, followed by EAC and AC (Table 1). On redness (CIE a^*) and yellowness (CIE b^*), the breast from AC resulted in higher values than other two chilling. The characteristics of darker, redder, and more yellow color on AC breasts are expected due to surface dehydration. These results are consistent with the findings of Huezo et al. (2007) for broiler carcasses chilled by air or water immersion. They suggested that dryness on carcass surface could contribute to the difference in color between chilling methods.

The shear force of cooked breast stored for 24 h and properties of breast protein gels are presented in Table 2. No chilling method was found for properties of breast fillets and protein gels ($p > 0.05$). In shear force, the breasts of WC generated a numerically higher shear value (tougher) than those of AC or EAC although there was no statistically difference ($p > 0.05$). Table 3 shows sensory properties of cooked breast samples evaluated by a total of 210 panelists. Sensory scores of flavor, texture, and overall acceptability were similar ($p > 0.05$) regardless of chilling methods. However, breasts from AC recorded higher juiciness ($p < 0.05$) than those of WC or EAC.

IV. CONCLUSION

Three chilling methods (water, air or evaporative air) showed no significant difference in moisture content and cooking yield of deskined breast fillets. No significant difference also was found in the properties of breast protein gels and consumer sensory except higher juiciness from air chilled breast. In fillet color, WC showed a higher CIE L^* value than two other chilling methods while AC generated more red (higher CIE a^*) and yellow (higher CIE b^*) color than WC and EAC. Every year, approximaetely 9 billion broilers are processed and 63 billion gallons (7 gallon per bird) are consummed. Ninty three percent of the 9 billion broilers were reported to be further procesed. The United Nations continuously reported both water scarcity issues and limied freshwater capacity for processing pollutants from industrial, urban and agricultural uess. Considering no effects on quality improvement by WC, while requring large water consumption and subsequent waste water discharging, air chilling technology is required to be furthre evaluated and compared for potential advanges such as minized water consumption, reduced waist water, and potential of extemded shelf-life over the water chilling.

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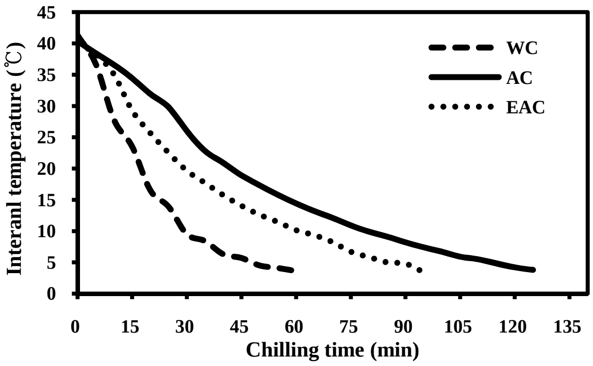

Fig. 1. Temperature changes in breast muscle of broiler carcasses during water, air, and evaporative air chilling. WC: water chilling; AC: air chilling; EAC: evaporative air chilling.

Table 1. Effects of three chilling[1] methods on skinless breast color[2], pH[3], moisture[4], and cooking yield[5]

Chilling	pH	Moisture (%)	Cooking yield (%)	CIE *L**	CIE *a**	CIE *b**
WC	$5.63^{a} \pm 0.02$	$75.05^{a} \pm 0.13$	$75.86^{a} \pm 1.32$	$53.35^{a} \pm 0.28$	$2.85^{b} \pm 0.11$	$2.58^{b} \pm 0.14$
AC	$5.52^{b} \pm 0.02$	$75.38^{a} \pm 0.21$	$74.38^{a} \pm 1.07$	$49.55^{c} \pm 0.29$	$3.35^{a} \pm 0.09$	$3.38^{a} \pm 0.22$
EAC	$5.49^{b} \pm 0.02$	$75.58^{a} \pm 0.10$	$75.51^{a} \pm 1.24$	$51.06^{b} \pm 0.26$	$3.01^{b} \pm 0.09$	$2.95^{ab} \pm 0.19$

All values are mean ± standard error of three replicates.
[1]Chilling treatments: WC (water chilling), AC (air chilling), EAC (evaporative air chilling).
[2]Values measured immediately after chilling
[3, 4, 5]Values measured after 24 h aging
[a,b]Means within a columm with unlike superscript letters are different ($p < 0.05$).

Table 2. Effect of three chilling methods on shear force of cooked fillets and properties of protein gels for moisture content, cooking yield, shear stress, and shear strain

Chilling[1]	Moisture (%)	Cooking yield (%)	Shear stress (kPa)	Shear strain	Shear force (N)
WC	$78.77^{a} \pm 0.06$	$85.80^{a} \pm 2.46$	$25.57^{a} \pm 0.67$	$1.34^{a} \pm 0.05$	$13.68^{a} \pm 1.25$
AC	$78.80^{a} \pm 0.16$	$85.34^{a} \pm 1.68$	$25.84^{a} \pm 0.64$	$1.34^{a} \pm 0.04$	$11.95^{a} \pm 0.34$
EAC	$78.73^{a} \pm 0.12$	$86.50^{a} \pm 1.97$	$25.70^{a} \pm 0.84$	$1.38^{a} \pm 0.04$	$11.35^{a} \pm 0.40$

All values are mean ± standard error of three replicates.
[1] Chilling treatments: WC (water chilling), AC (air chilling), EAC (evaporative air chilling).
[a-c] Means within a columm with unlike superscript letters are different ($p < 0.05$).

Table 3. Effect of three chilling methods on consumer sensory properties of cooked broiler breasts after 24 h of storage

Chilling[1]	Flavor	Texture	Juiciness	Overall acceptability
WC	$6.42^{a} \pm 0.11$	$6.40^{a} \pm 0.11$	$6.17^{b} \pm 0.12$	$6.31^{a} \pm 0.11$
AC	$6.43^{a} \pm 0.11$	$6.72^{a} \pm 0.11$	$6.57^{a} \pm 0.12$	$6.24^{a} \pm 0.11$
EAC	$6.46^{a} \pm 0.11$	$6.41^{a} \pm 0.12$	$6.01^{b} \pm 0.13$	$6.48^{a} \pm 0.11$

All values are mean ± standard error of three replicates.
[1] Chilling treatments: WC (water chilling), AC (air chilling), EAC (evaporative air chilling).
[a-c] Means within a columm with unlike superscript letters are different ($p < 0.05$).