

PROCESSING, PRODUCTS, AND FOOD SAFETY

Comparison of Air and Immersion Chilling on Meat Quality and Shelf Life of Marinated Broiler Breast Fillets

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ABSTRACT Marinated broiler breast fillets were evaluated using both air- and immersion-chilling treatments. Ninety fillets from air-chilled broiler carcasses and 90 fillets from immersion-chilled broiler carcasses were obtained from a processor to determine differences in meat quality, sensory, and shelf life. At 24 h postmortem, the fillets were vacuum-tumbled (25 in Hg, 30 min, 14 rpm, 4°C) in 2 replications per treatment with a 20% solution (wt/wt) yielding 0.70% NaCl and 0.45% sodium tripolyphosphate in the final product. One-third of the fillets in each replication were packaged in a tray covered with plastic wrap and stored in retail cases to simulate retail shelf-life conditions. The remaining fillets were stored at 4°C for 24 h until analysis for marinade retention, cook loss, consumer evaluation, and objective tenderness. The immersion-chilled fillets had a significantly lower pH (5.56) and were lighter (L^* 54.73) when compared with

the air-chilled fillets (5.64, L^* 50.13, respectively). The air-chilled fillets had a significantly higher marinade pick-up (15.51%) than the immersion-chilled (14.07%) fillets. However, there were no significant differences in cook loss percentage in either treatment (approximately 20.03). Shear value was significantly higher in the immersion-chilled fillets (4.14 N), indicating less tender meat than the air-chilled fillets (3.62 N). In the consumer analyses, the air-chilled fillets were significantly different. Of the respondents that noted differences, 19% indicated differences in texture, and 9.67% indicated taste differences. The air-chilled treatment had significantly lower aerobic plate count in postpackaging d 0, 3, and 9. Also, coliforms were significantly lower in the air-chilled treatment through d 6. Therefore, air chilling carcasses may improve color, marination yield, tenderness, and increase the shelf life of retail-packaged broiler breast fillets.

Key words: air chilling, immersion chilling, meat quality, tenderness, shelf life

2008 Poultry Science 87:368–372
doi:10.3382/ps.2007-00213

INTRODUCTION

The primary objective of chilling poultry is to reduce microbial growth to a level that will maximize both food safety and shelf life. Chilling, required for poultry, has been an accepted processing step in the preservation of many food commodities for numerous years (Dickens and Whittemore, 1995). Carcass temperature is reduced to 4°C or less as soon as possible after evisceration (1 to 2 h postmortem) and must be 4°C or less within 4 h of slaughter (USDA, 1995). The 2 most common methods of chilling broilers are immersion chilling, in which the product is immersed in chilled (0 to 4°C) water, and air chilling, in which carcasses are misted with water in a room with circulating chilled air. Immersion chilling is the most frequently used in the United States, whereas air chilling is the most frequently used in Europe, Brazil, and Canada (Sams, 2001).

Immersion-chilled carcasses can absorb water in the skin and surrounding fat during chilling. Immersion chillers are usually counter-current flow, in which the carcasses and water flow in opposite directions to maximize chilling rate. Because of the temperature gradient created with this counter-current immersion flow system, the carcasses can retain some water (USDA, 2001). Young and Smith (2004) found that immersion-chilled carcasses absorbed 11.7% moisture during chilling and retained 6.00% of that moisture during cutting and 3.90% during postcutting storage. In January 2001, the USDA-Food Safety Inspection Service announced a new requirement intended to improve the safety of raw poultry. The new rule requires processors to justify any retained water in raw products as an unavoidable consequence of their process used to meet food safety requirements (USDA, 2001). Processors will be required to list clearly either the percentage of retained water or the maximum percentage of absorbed water on each product label. Those processors that demonstrate there is no retained water in their products may choose to not label their product with a retained water statement or to make a no-retained water claim on the product (USDA, 2001).

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Received May 31, 2007.

Accepted November 1, 2007.

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Table 1. Quality measurements of marinated air- and immersion-chilled fillets¹

Chilling method	pH (24 h postmortem)	L* value (24 h postmortem)	Shear force (N)
Air	5.64 ^a	50.13 ^b	3.62 ^b
Immersion	5.56 ^b	54.73 ^a	4.14 ^a
Pooled SEM	0.01	0.43	0.07

^{a,b}Means with same letter within a column are not significantly different ($P < 0.05$).

¹n = 160.

In air chilling, cold air instead of water is used as a chilling medium. Air is blown over cooling elements and then circulated around the room at a fairly high speed (Barbut, 2002). Advantages of using air chilling include no moisture pickup and a drier product that does not show much exudation when packed in trays. Young and Smith (2004) found that air-chilled carcasses lost an average of 0.68% of their postslaughter weight during storage. Some processors also claim that the microbial quality of the air-chilled product is better than that of a water-chilled product (Barbut, 2002; Sanchez et al., 2002).

The 2 chilling systems have different effects on the microbial quality of poultry carcasses (Sams, 2001; Sanchez et al., 2002). During immersion chilling, cold water flows in a counter-current direction, creating a continuous clean water system for the birds during chilling. This process provides a greater reduction in total bacterial load and results from the washing action achieved with immersion chilling (Dickens and Whittemore, 1995). However, the extensive bird-to-bird contact via immersion chilling results in pathogen cross-contamination to other carcasses (Bailey et al., 1987). This cross-contamination results in a greater incidence of pathogen-positive birds in immersion-chilled carcasses than air-chilled carcasses.

Marination of broiler breast meat has become an integral part of the poultry industry due to the increase in consumer and retailer demand for further-processed, ready-to-eat foods (Alvarado and Sams, 2002). Because of the moisture-retention rule, most processors marinate broiler breast fillets to ease possible labeling issues with retained water.

Marination has also been used as a method of tenderization. A typical marinade solution results in a final concentration of salt (1 to 3%) and sodium tripolyphosphate (0.5%). It has been found that sodium ions in marinades produce a tenderizing effect due to the repulsion by association of the ions with the proteins (Sams, 2001). This repulsion allows increased water uptake, which increases

moisture content of the cooked meat and increases tenderness (Alvarado and Sams, 2002).

Marination quality parameters in broiler meat may be affected based on chilling system, because differences exist in quality parameters and moisture uptake in broiler carcasses either immersion-chilled or air-chilled. In the United States, there are few broiler-processing facilities that currently air chill. However, no previous research has been conducted comparing air and immersion chilling on marination parameters and marinated product quality. Therefore, the objective of this study was to compare the effects of air and immersion chilling on meat quality and shelf life of marinated broiler breast fillets.

MATERIALS AND METHODS

A total of 160 nonmarinated immersion-chilled fillets and 160 nonmarinated air-chilled fillets in 2 trials and 3 replications per trial were delivered to the Texas Tech University Meat Lab at 24 h postmortem (4°C) from large-scale processors. Each fillet was individually weighed, tagged, and color values (L*, a*, b*; Spectrophotometer CM-2002, Minolta Camera Co. Ltd., Tokyo, Japan) were determined in triplicate on each fillet. The pH (IQ 150, 60° Tip Probe, IQ Scientific Instruments, San Diego, CA) was measured (probe method) in each fillet at 24 h postmortem, before marination. Fillets were vacuum-tumble-marinated (LT 5 Koch Tumbler, Lance Industries, Allenton, WI; 30 m, 14 rpm, and 25 in Hg) at 4°C by treatment (air and immersion) in 2 replications with a 20% wt/wt solution resulting in a final concentration of 1% salt and 0.45% sodium tripolyphosphate.

Each fillet was weighed individually for marinade pickup (%) at 1 h postmarination. Twenty air-chilled and 20 immersion-chilled fillets (10 from each replication) were packaged with 2 fillets per package in tray packs with saran overwrap to simulate retail standards. These fillets were used for microbial analysis and stored in the 4.4°C retail case.

Table 2. Water-holding capacity measurements of marinated air- and immersion-chilled fillets¹

Chilling method	Pickup (%)	Retention (%)	Cook loss (%)	Cooked moisture (%)
Air	15.51 ^a	98.55 ^a	20.52 ^a	25.46 ^b
Immersion	14.07 ^b	97.04 ^b	19.68 ^a	26.42 ^a
Pooled SEM	0.35	0.08	0.33	0.28

^{a,b}Means with same letter within a column are not significantly different ($P < 0.05$).

¹n = 15 (cooked moisture); n = 140 pickup, retention, cooked moisture.

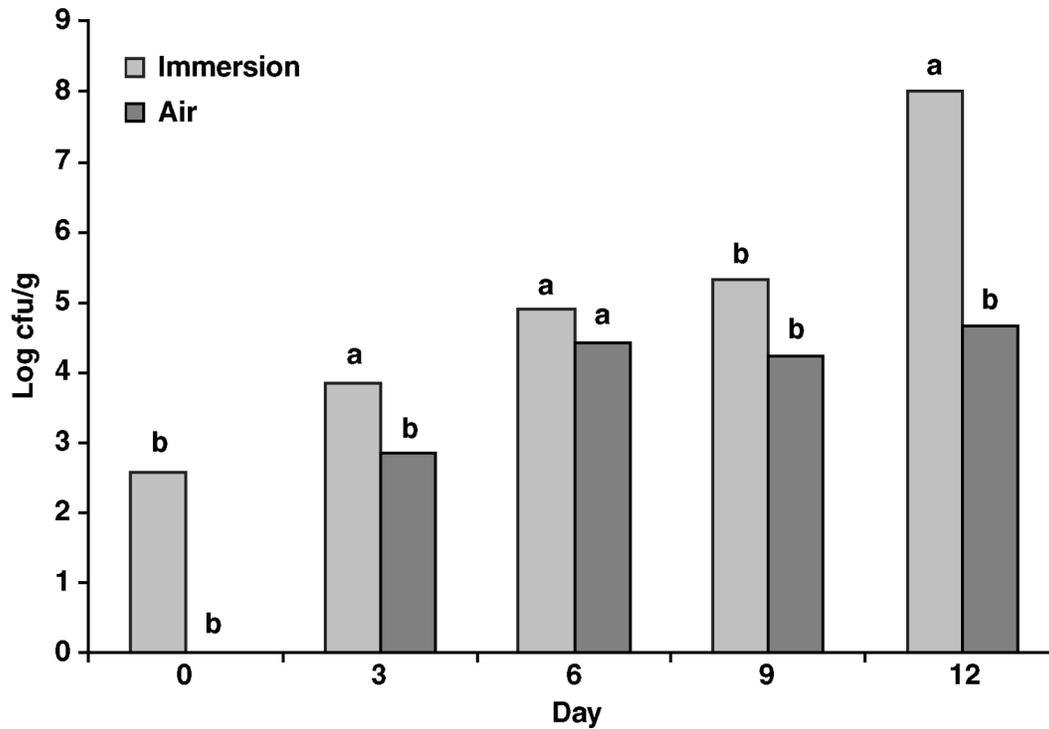


Figure 1. Aerobic plate counts (log cfu/g) of marinated air- and immersion-chilled fillets ($n = 20$). ^{a,b}Means with the same letter within a day are not significantly different ($P < 0.05$).

Aerobic plate count (3M Petrifilm Aerobic Plate Count, 3M Microbiology Products, St. Paul, MN) and coliform counts were performed on 2 packages of air-chilled and 2 packages of immersion-chilled fillets (per replication). Microbial analysis was performed on d 0 (day of marination), 3, 6, 9, and 12. All of the remaining fillets were placed in 4°C coolers overnight. The following day, each fillet was weighed individually for retention (%) of marinade. Half of the remaining fillets (60 air and 60 immersion) were cooked in aluminum-lined and covered pans in the convection oven (Blodgett Mark V-111, Blodgett, Burlington, VA) at 350°F (177°C) to an internal temperature of 71°C (Sams, 1990). Half of the cooked fillets were removed from the oven, weighed, and wrapped individually in foil and stored at 4°C until shear test was performed (2 h postcook). Shear test was performed on cooked fillets after the temperature had dropped to around 22°C (room temperature). The razor blade method (Cavitt et al., 2004b) was performed in triplicate on each fillet. Moisture analysis, oven method (AOAC, 1998), was performed in duplicate on 15 samples per treatment.

The remaining cooked fillets were sent to the Texas Tech University Human Sciences Building for a consumer taste panel. A triangle test (70 members) was performed to determine if difference between treatments existed. Panelists were randomly presented samples (2 from 1 treatment and 1 from the second treatment) identified by random 3-digit codes. Half of the panelists served were given 2 marinated air-chilled samples and 1 marinated immersion-chilled sample, whereas the remaining panelists were given 2 marinated immersion-chilled samples

and 1 marinated air-chilled sample. Between each sample, panelists were instructed to cleanse their palate with distilled deionized water. The sensory facility had individualized booths, red lights to avoid sample bias, and panelists were served through a hatch door. Panelists were asked to comment on their decision.

Statistical analysis was determined using PROC GLM in SAS (SAS Institute Inc., Cary, NC) and Duncan's mean separation test to determine significance between treatments ($P < 0.05$). There was no trial \times treatment interaction, so data were pooled within a parameter by treatment.

RESULTS AND DISCUSSION

The air-chilled fillets had a lower L^* value, higher pH, and lower shear force values when compared with immersion-chilled fillets (Table 1). Research has shown that there is a significant relationship between raw breast meat color and raw meat pH (Qiao et al., 2001). In general, a lower pH is associated with denatured sarcoplasmic proteins, which cause scattering of light and therefore make the meat appear lighter, as indicated by a higher L^* value (Swatland, 1993). Also, lightness (L^*) had the highest correlation of the L^* , a^* , and b^* color values in fillets with PSE-like conditions. The results of this study are similar to Mielnik et al. (1999), who found that air-chilled color was darker (lower L^* value). It is important to note that factors other than chilling can cause color differences among birds. For example, stress and nutrition also play an important factor in L^* value determination (Sams, 2001).

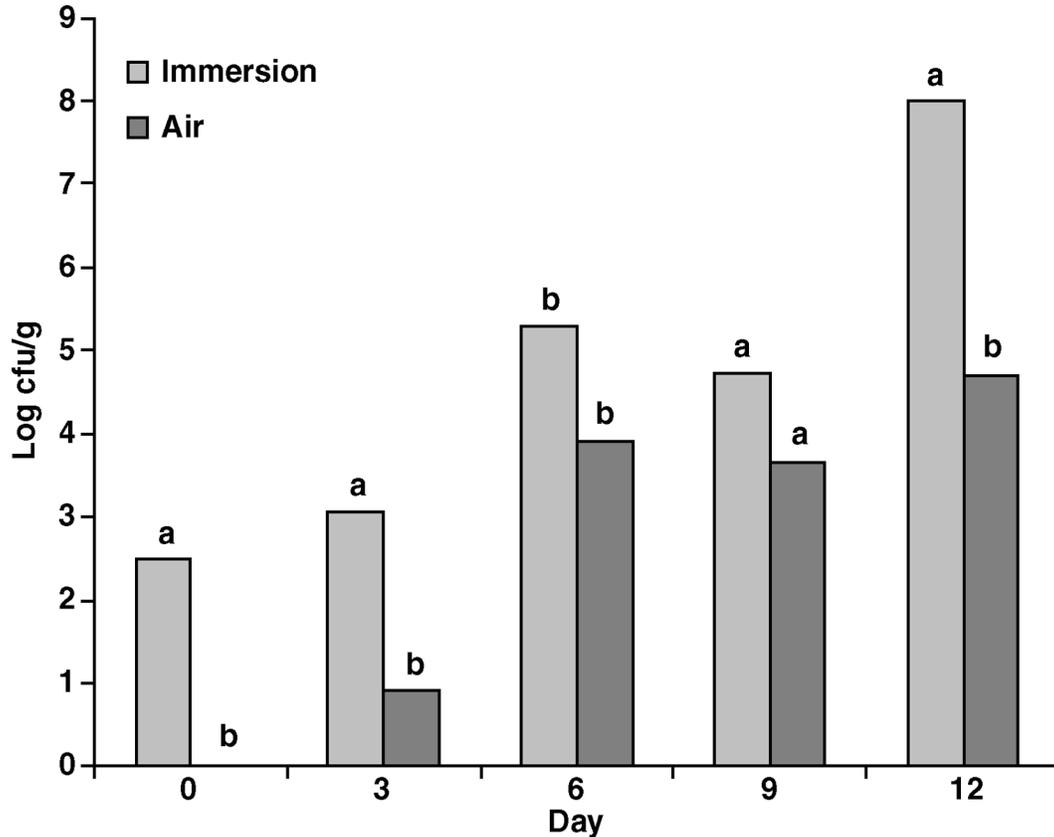


Figure 2. Coliform counts (log cfu/g) of marinated air- and immersion-chilled fillets ($n = 20$). ^{a,b}Means with the same letter within a day are not significantly different ($P < 0.05$).

Water-holding capacity is very important in meat quality and is affected by many factors including pH of marinades and meat. Poultry meat with low pH has been associated with low water-holding capacity, which results in increased cook loss and drip loss (Froning et al., 1978; Barbut, 1993; Northcutt et al., 1994). Air-chilled carcasses had an increased marinade pickup and retention in the breast fillets compared with the immersion-chilled treatment. These results may be due to the increased moisture lost during air chilling. With increased moisture loss, the fillets from the air-chilled carcasses may be able to pick up and retain more marinade than the immersion-chilled fillets, which have a higher moisture content. Fillets from air-chilled carcasses and immersion-chilled carcasses had similar cook loss. This lack of difference could be due to the increase in marination uptake of the air-chilled fillets equalizing the moisture in the fillets. However, the overall yield (%) from postmarination through cook loss was significantly different between treatments, indicating that the overall change in moisture during the marination and cooking process was affected by chilling treatment (79% air-chilled, 75% immersion-chilled; $P < 0.05$).

Cooked meat moisture was also measured in this study as another form of water-holding capacity. Fillets from the immersion-chilled carcasses had a higher cooked meat moisture when compared with the air-chilled fillets (Table 2). This could be due to the slight increase in cooked loss associated with the air-chilled breast fillets.

Shear value was used as a measurement of tenderness in this study. The fillets from the air-chilled carcasses were more tender than the fillets from the immersion-chilled carcasses. These differences could be due to many factors including aging and deboning times postmortem. Because these fillets were obtained from air-chilled and immersion-chilled broiler processors, it is difficult to determine exact aging times of these fillets. However, these shear force values are well within the acceptable ranges for consumers (Cavitt et al., 2004a). Therefore, even though there are statistical differences in shear value between treatments, this is not a difference consumers can detect.

Air chilling had increased shelf life with lower aerobic plate counts (Figure 1) and lower coliform counts (Figure 2). It is thought that at least the risk of cross-contamination is greater with immersion chilling, because the broiler carcasses come into contact with each other (Sanchez et al., 2002). During air chilling, the bird-to-bird cross-contamination may be decreased, because the birds are individually hung on shackles during chilling. Fluckey et al. (2003) indicated that air-chilled broilers had a lower incidence of *Salmonella* and *Campylobacter* as well as significantly lower psychrotrophs when compared with immersion-chilled carcasses.

Sensory evaluation is very important to consumers. If a product is not aesthetically pleasing or does not have a good flavor, consumers are less likely to purchase and

repurchase the product. A triangle test was used to determine differences in treatments in this study. A triangle test only determines if differences exist between samples (in this case, air- vs. immersion-chilled breast fillets) and not a preference of one sample over the other sample. In both trials, the minimum number of correct answers to establish significance at 95% probability level was reached. Therefore, differences are detectable between the air-chilled and immersion-chilled samples. Based on the comments of the respondents that noted differences, 19% indicated differences in texture and 9.67% indicated differences in flavor. The texture differences could be due to the differences noted in the water-holding capacity (immersion chilling had higher cooked moisture) and the shear force (immersion had high shear force).

The implications of this study are that air chilling of broiler carcasses has potential to improve meat quality, further-processing yields from marinated poultry products, and shelf life of poultry products.

ACKNOWLEDGMENTS

We would like to thank MBA Poultry (Waverly, NE) for their support and help with this research project.

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