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Impact of carcass scalding and chilling on muscle proteins and meat quality of broiler breast fillets☆

Brian C. Bowker*, Hong Zhuang, Richard J. Buhr

USDA, Agricultural Research Service (ARS), Richard Russell Research Center, 950 College Station Rd., Athens, GA 30605, United States

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ABSTRACT

The objective of this study was to determine the effects of broiler carcass scalding and chilling methods on meat quality and muscle proteins. During processing, carcasses were hard (60 °C, 1.5 min) or soft (52.8 °C, 3 min) scalded, and either immersion chilled (IC: 0.5 °C, 40 min) or air chilled (AC: 0.5 °C, 120 min). Breast fillets were deboned at 4 h postmortem and used for measuring meat quality and muscle protein characteristics. Scalding by chilling treatment interaction effects on meat quality were not observed. Air chilled carcasses had greater pH_{24}, and reduced drip loss and shear force compared to IC carcasses. Cook yield, color ($L^*a^*b^*$), and moisture content were not different between chilling treatments. Scalding treatments did not influence quality traits. Sarcoplasmic protein solubility was not influenced by chilling treatment, but was greater in hard versus soft scalded carcasses. Myofibrillar protein solubility was greater in fillets from soft scalded IC carcasses. Alterations in the electrophoretic profiles of the myofibrillar and sarcoplasmic proteins due to treatments indicated minor changes in protein degradation and solubility. Data suggest that while only chilling method influenced meat quality, both scalding and chilling methods influenced protein solubility and degradation in breast fillets deboned 4 h postmortem.

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1. Introduction

Carcass chilling and scalding are important initial steps in poultry processing that influence product safety and quality. The primary purpose of carcass chilling is to rapidly reduce carcass temperatures and the growth of pathogenic and spoilage microorganisms on carcasses (James, Vincent, de Andrade Lima, & James, 2006). Regulations in the U.S. require broiler carcasses to be at 4.4 °C or less within 4 h postmortem (FSIS-USDA 1996). The two most common methods for chilling broiler carcasses are immersion chilling (IC) and air chilling (AC). With IC, carcasses are cooled by immersion in ice-water (0–4 °C) tanks with air agitation and countercurrent flow to increase heat exchange efficiency. With AC, carcasses are placed in a room and chilled by cold air (−7 to −2 °C) circulation.

Although IC is the predominant method for chilling broiler carcasses in the U.S., regulations regarding retained water in raw meat and poultry products (FSIS-USDA, 2001) have stimulated additional interest in AC. As a result, a number of publications have compared IC and AC effects on meat quality and sensory attributes in chicken breast fillets (Huezo, Northcutt, Smith, & Fletcher, 2007; Jeong, Janardhanan, Booren, Harte, & Kang, 2011; Jeong, Janardhanan, Booren, Karcher, & Kang, 2011; Zhuang, Savage, Smith, & Berrang, 2008, 2009). Comparing the specific effects of chilling method on meat quality is often complicated by variations in scalding procedures prior to chilling both within and between studies.

Immediately following exsanguination, carcasses are scalded by immersion in heated water to aid in loosening feathers prior to removal. Typically carcasses are either soft (50–54 °C) or hard (61–63 °C) scalded depending upon intended use. The warmer temperature of hard scalding removes the outer epidermal layer of the skin, while soft scalding does not remove the cuticle and yields carcasses with a more yellow skin surface. Air chilled carcasses are typically soft scalded because the removal of the outer epidermal layer with hard scalding makes AC carcasses more susceptible to dehydration and discoloration. Although scalding effects on carcass skin are known and the impact of chilling on meat quality has been

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* Corresponding author. Tel.: +1 706 546 3610; fax: +1 706 546 3607.
E-mail address: brian.bowker@ars.usda.gov (Brian C. Bowker).

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studied, little is known about the interacting effects of scalding and chilling on fresh meat quality.

Variations in meat quality traits such as texture, color, and water-holding capacity result from interacting biochemical and physicochemical changes that occur within the tissue during the transformation of muscle to meat. Differences in meat quality are linked to alterations in muscle protein integrity and ultrastructure in response to postmortem conditions within the muscle. The influence of processing steps, such as scalding and chilling, on meat quality is largely a function of their effect on the postmortem temperature decline within the muscle. Postmortem muscle temperature influences key factors such as rigor mortis onset and resolution, pH decline, and aging related protein degradation. The effects of different broiler carcass scalding and chilling methods on the muscle proteins related to meat quality are relatively unknown. Thus, the objective of this study was to determine the impact of scalding (hard or soft) and chilling (immersion or air) methods on meat quality and muscle protein characteristics.

2. Materials and methods

2.1. Slaughter and carcass treatment

Ninety-six Ross 708 strain broiler chickens (5–6 wk old, 2.5 kg average body weight) were transported (15 min) to the Richard B. Russell Agricultural Research Center pilot processing plant (Athens, GA) on each of two experiment days in December for slaughter according to the approved procedures of the institutional animal care and use committee. Birds were electrically stunned (15 V DC, 500 Hz, 8 s) using a brine-type stunner, exsanguinated using an automated knife, and bled for 2 min. Carcasses were then hard (60 °C, 1.5 min) or soft (52.8 °C, 3 min) scalded with a triple tank configuration. Carcasses were mechanically defeathered and manually eviscerated. Carcasses were then air chilled (AC: 0.5 °C, 85–90% RH) for 120 min or immersion chilled (IC: 0.5 °C in air agitated ice water) for 40 min. The parameters of the chilling regime were selected based on published temperature profiles (Huezo, Smith, Northcutt, & Fletcher, 2007) and their ability to reduce broiler carcass temperatures to 4 °C within the pilot processing plant. Breast fillets were deboned at 4 h postmortem. Three batches of each scalding treatment were processed on each experiment day with 16 carcasses per batch. On each experiment day, seven carcasses were randomly selected from each of the four scalding-chilling treatment combinations (total of 56 carcasses) for evaluation of meat quality and protein traits.

2.2. Meat quality measurements

Following deboning, left breast fillets were used for measurement of pH, color, drip loss, and moisture content. Right breast fillets were individually placed in sealed plastic bags and stored at 4 °C until 24 h postmortem for measurement of cooking yield and texture. Muscle pH at 4 h was measured with a Hach H280GB pH meter and a PH57-SS spear-shaped probe (Hach Inc., Loveland, Colo., U.S.A.) inserted into the cranial end of the fillet. Meat color (CIE $L^*a^*b^*$) was measured (3 averaged readings) with a Minolta spectrophotometer CM-700d (Konica Minolta Inc., Ramsey, N.J., U.S.A.) on the central portion of the dorsal surface of the skinless breast fillet. At 6–8 h postmortem, a 40-g sample was removed by a coring device from the fillet for drip loss determination. The core was placed on a mesh screen in a covered plastic cup and stored at 2 °C for 96 h. Drip loss was expressed as a percentage of the weight lost over 96 h. Breast meat (25-g) was minced for 1 min in a food processor (HC306, Black & Decker Corp., Towson, Md., U.S.A.) and duplicate 5-g aliquots were used for measuring moisture content (AOAC, 1990). Muscle from the left fillet was stored at 4 °C until 24 h postmortem. Duplicate 1-g samples were then blended with 10 mL deionized water for determination of ultimate muscle pH (pH_{24}). The remaining portions of the left fillets were stored at −80 °C for one to two months prior to evaluation of muscle protein attributes. At 24 h postmortem, right fillets were cooked in vacuum bags to 78 °C in a combi steam oven (MCS-6, Henny Penny Corp., Eaton, Ohio, U.S.A.) according to the procedure of Zhuang and Savage (2008). Endpoint temperatures of the fillets were monitored with a digital thermometer connected to needle microprobes. Fillet weights were recorded before and after cooking to determine cooking yield. Two 1.9-cm × 1.9-cm strips were cut from the center portion of each cooked fillet parallel to muscle fiber direction. Room temperature strips were sheared perpendicular to the muscle fibers using a texture analyzer (TA-XT2, Texture Technologies Corp., Scarsdale, N.Y., U.S.A.) equipped with a Warner–Bratzler shear device and a 50-kg load cell with a crosshead speed of 4 mm/s to determine peak shear force (N).

2.3. Sarcomere length

Sarcomere length was measured in myofibrils isolated according to Weaver, Bowker, and Gerrard (2008). For each sample, 20 myofibrils with at least five consecutive intact sarcomeres were measured directly using phase contrast microscopy (Axio Imager A2, Carl Zeiss MicroImaging, LLC, Gottingen, Germany), a 100× oil immersion objective, and imaging software (v 6.1 ZEN 2011 Blue Edition, Carl Zeiss MicroImaging, LLC).

2.4. Protein solubility

To measure sarcoplasmic protein solubility, duplicate 1-g muscle samples were homogenized with 10 mL of cold 25 mmol/L potassium phosphate buffer (pH 7.2). Samples were placed on a rocker plate at 4 °C for 20 h and then centrifuged at 2600 × *g* for 30 min. Supernatant was decanted and protein concentration was measured using the biuret assay (Gornall, Bardawill, & David, 1949) with BSA standards. Total protein solubility was similarly determined in 1.1 mol/L KI, 0.1 mol/L potassium phosphate (pH 7.2) buffer. Myofibrillar protein solubility was calculated from the difference between total and sarcoplasmic protein solubility.

2.5. Myofibrillar and sarcoplasmic protein isolation

Myofibrillar and sarcoplasmic protein fractions were isolated by subcellular fractionation (Pietrzak, Greaser, & Sosnicki, 1997). Muscle samples (1-g) were homogenized in 20 mL of cold homogenization buffer (50 mmol/L KCl, 20 mmol/L Tris, pH 7.0, 2 mmol/L EDTA, 4 mmol/L $MgCl_2$, 5 mmol/L 2-mercaptoethanol, 0.1 mmol/L PMSF, and 1 mL/100 mL Triton X-100). The homogenate was centrifuged at 10,000 × *g* for 10 min and the supernatant (S1) was decanted and saved. Twenty mL of cold buffer (75 mmol/L KCl, 10 mmol/L KH_2PO_4, 2 mmol/L $MgCl_2$, 2 mmol/L EGTA, pH 7.0) were added to the pellet and homogenization was repeated. An aliquot (1.0 mL) of this homogenate (P1) was saved and centrifugation was repeated. These steps were repeated to obtain S2, S3, P2, and P3 fractions. The biuret assay was used to determine the protein concentration of each fraction.

2.6. SDS-page

Myofibrillar and sarcoplasmic protein fractions were denatured (100 °C water for 3 min) in sample buffer containing 8 mol/L urea, 2 mol/L thiourea, 3 g/100 mL SDS, 75 mmol/L DTT, 25 mmol/L Tris–HCl (pH 6.8), and 0.004 g/100 g bromophenol blue (Yates & Greaser,