

Effect of Chilling Temperature of Carcass on Breast Meat Quality of Duck

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ABSTRACT An experiment was carried out to investigate whether variations in chill water temperature affect muscle shortening and meat quality in duck breast. Three chill water temperatures were applied to duck carcasses at 20 min postmortem for 30 min, including in ice water at 0°C, in cold water at 10°C, and in water at 20°C. Results revealed that carcass temperatures were different ($P < 0.05$) at 50 and 120 min of postmortem with lower temperatures at the 0°C treatment ($P < 0.05$). The pH over the first 24 h postmortem was not different ($P > 0.05$) among treatments, with the exception of 50 min postmortem. The pH of breast meat in the 0°C treatment was higher ($P < 0.05$) than that of 20°C treatment at 50 min postmortem (just after chilling). No other differences (P

> 0.05) in pH existed among treatments. Drip loss, cooking loss, and moisture content were not different for breast meat samples that were chilled at different temperatures. Differences ($P < 0.05$) were found in CIE (L^* , a^* , and b^*) color values. Lightness (L^*) increased, whereas redness (a^*) decreased as the chill water temperature increased. Lower yellowness (b^*) was found in the breast meat samples at the 10°C chill water temperature. However, shear force, sarcomere length, and protein solubility were not different ($P > 0.05$) among the breast meat samples chilled at different chill water temperatures. It may be concluded that chilling duck carcasses at different temperature ranges from 0 to 20°C did not influence muscle shortening or meat quality, except in regard to breast meat color.

Key words: duck, chilling water temperature, breast meat quality

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INTRODUCTION

Duck is a waterfowl and has a different physiology than other poultry. Duck breast has a higher red muscle fiber content as compared with the chicken breast (Smith et al., 1993) and is considered a red meat. Although duck is very popular in many regions of the world, duck processing has not been researched extensively. During meat processing and storage, biochemical processes and chemical changes that occur in muscle during the first 24 h postmortem play a great role in the ultimate quality and palatability of meat. Therefore, the quality and palatability of duck meat could be influenced by the chilling processes that carcasses are subjected to after slaughter.

Muscle types vary in their potential to cold shortening during chilling, with red muscle being more susceptible than white (Bendall, 1975). Duck breast meat is composed of 70 to 90% oxidative red fibers (type IIA; Baeza, 1995), whereas chicken breast meat is almost all type IIB (white; Smith and Fletcher, 1992).

In a previous experiment, differences were reported between chicken and duck breast meat regarding the pH decline between slaughter and 24 h postmortem (Ali et al., 2007). Honikel et al. (1981) reported that when beef muscle was exposed to temperatures above 25°C, or below 4°C, muscle shortening increased and was found to be directly related to greater amounts of muscle drip loss. Joo et al. (1999) also found that the color and water-holding capacity of pork were affected by muscle temperature during slaughter and storage due to denaturation of sarcoplasmic proteins. Still, limited research has been published with regard to type IIA muscle as compared type IIB and type I.

Sarcomere length is a good indicator of muscle shortening. The relationship between cold shortening and sarcomere length was first demonstrated clearly by Herring et al. (1965), who showed the direct relationship between sarcomere length, fiber diameter, and toughness. Sams and Janky (1991) stated that chilling has a greater effect on slowing the rate of rigor mortis development in red fibers as compared with white fibers. For beef and lamb, employing chilling parameters that minimize cold shortening is important and can be best addressed by ensuring that muscle temperatures are not below 10°C before the pH reaches 6.2. In pork, however, a more rapid chilling process is needed to reduce pale, soft, and exudative (PSE) meat, with a rec-

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ommended internal muscle temperature of 10°C at 12 h and 2 to 4°C at 24 h (Savell et al., 2005).

The demand for duck meat is increasing day by day. Thus, research on duck processing should be conducted to find out whether any cold shortening occurs during carcass chilling. Also, it is necessary to determine the extent of shortening that occurs during processing, which might contribute to the quality, textural variability, and toughness of duck breast muscle. Furthermore, it is necessary to determine ways to minimize any variability in quality or texture. Therefore, the present study was undertaken to investigate the effects of various chilling methods on the toughness and meat quality parameters of duck breast meat.

MATERIALS AND METHODS

A total of 78 ducks (Chungdong ori, 48 d-old, *Anas platyrhynchos*) were slaughtered in a processing plant (Hadong, Korea) by a conventional neck cut and were then scalded and eviscerated on a conveyer belt in 2 different trials with 39 ducks in each trial. Duck carcasses were harvested from the plant just before chilling at 20 min postmortem. In each trial, prechilled samples that were used for determining carcass temperature and pH were collected from 3 carcasses before chilling, whereas the remaining 36 carcasses had 3 different chilling temperatures applied in 3 different chilling boxes made of insulating cork sheet material, with 12 ducks for each water chilling temperature. The treatments were as follows: chilling for 30 min in ice water at 0°C, chilling for 30 min in cold water at 10°C, and chilling for 30 min in water at 20°C. The pH and carcass temperatures at 20 and 50 min (just after chilling) were measured in the processing plant. After this, the carcasses were transported in a box with ice that was maintained at 4°C to the meat science laboratory of Gyeongsang National University. They were then stored in a cold storage room at 4°C.

Temperature and pH were measured from the left breast just after chilling (at 50 min postmortem), and at 120 min, 180 min, and 24 h postmortem from 3 duck carcasses of each treatment and time period for each trial. After 24 h, the right breast meat from 36 carcasses of each trial was removed and cooking loss, drip loss, moisture content, CIE* color values, sarcomere length, and protein solubility were measured, and SDS-PAGE gel electrophoresis was performed, using the right breast meat samples in the raw state, whereas shear force values were measured from cooked samples after measuring the cooking loss.

Temperature and pH Measurement

Before taking samples for pH measurement, carcass temperatures were recorded from the anterior portion of the deep left breast by inserting a thermometer. For pH measurement, samples (3 g), taken from the up-

per portions of each breast, were homogenized using a polytron homogenizer (T25basic, IKA Works(Asia) Sdn Bhd, Rawang, Malaysia) with distilled water (27 mL) for 10 s; pH was then measured using a pH-meter (MP230, Mettler, Switzerland).

Moisture Content, Drip Loss, and Cooking Loss

The samples from each breast were analyzed for moisture by the standard AOAC procedure (1995). From each sample, a standardized muscle cylinder (weighing about 30 g) was suspended in an inflated plastic box (4°C) for 24 h (48 h postmortem), and percentage drip loss was measured as described by Joo et al. (1995), where drip loss (%) = [(sample weight – sample weight after 24 h)/sample weight] × 100.

The breast meat samples were broiled in a water bath temperature of 70°C for 30 min, surface dried, and weighed. Cooking loss was determined by expressing the cooked sample (B) weight as a percentage of the precooked sample (A) weight. Cooking loss (%) = [(A – B)/(A)] × 100.

Shear Force

Shear force was measured using the Instron Universal Testing Machine (model 3343, Instron Co., Norwood, MA) equipped with a Warner-Bratzler shear device. From each cooked breast meat sample, a 0.5 × 4.0 cm (approximately 2.0 cm²) cross section was cut for shear force measurements. The meat samples were placed at right angles to the blade. Crosshead speed was 100 mm/min and full scale load 50 kg. An average of 9 readings was taken from each cooked breast meat sample.

Color Analysis

Immediately after deboning, the surface color (CIE L*, a*, b*) of the duck breast was measured using a Minolta Chromameter (Minolta CR 301, Tokyo, Japan). The chromameter was calibrated using a standard white ceramic tile before measuring each water-chilled sample. Three random readings were taken from each sample of breast meat, from similar areas of the inner side (bone attachment side) of breast meat.

Sarcomere Length

One- to two-gram samples were placed in a vial with solution A (0.1 M KCl, 0.39 M boric acid, and 5 mM ethylenediaminetetraacetic acid in 2.5% glutaraldehyde) for 2 h. The samples were then transferred to fresh vials containing solution B (0.25 M KCl, 0.29 M boric acid, and 5 mM ethylenediaminetetraacetic acid in 2.5% glutaraldehyde) for 17 to 19 h. On the following day, individual fibers were torn into pieces and placed

on a microscope slide with a drop of solution B. The slide was then placed horizontally in the path of a vertically oriented laser beam to give an array of diffraction bands on a screen. These bands were perpendicular to the long axis of the fibers as described by Cross et al. (1981). Sarcomere length (μm) = $(\{632.8 \times 10^3 \times D \times \text{SQRT}[(T/D)^2 + 1]\}/T) \times 100$, where D equals the distance (mm) from the specimen-holding device to the screen ($D = 98$ mm) and T equals the separation (mm) between zero and the first maximum band. An average of 10 sarcomere lengths was acquired from each breast meat sample.

Protein Solubility

To determine the solubility of the sarcoplasmic and total (sarcoplasmic + myofibrillar) proteins, 2 extractions were conducted. Sarcoplasmic proteins were extracted with 10 mL of ice-cold 0.025 M potassium phosphate buffer, pH 7.2 (Helander, 1961), which was added to each of the quadruplicate 1-g muscle samples. The samples were minced with scissors and homogenized in ice water with a polytron (T25basic, IKA Works(Asia) Sdn Bhd) on the lowest setting (3×4 s burst to minimize protein denaturation through heating) and then left on a shaker at 4°C overnight. Samples were centrifuged at $1,500 \times g$ for 20 min and the supernatant protein concentrations were determined by the Biuret method (Gornall et al., 1949). Total protein was extracted with 20 mL of 1.1 M potassium iodide in 0.1 M phosphate

buffer at 2°C, pH 7.2 (Helander, 1961), which was added to duplicate 1-g samples. The same procedures for homogenization, shaking, centrifugation, and protein determination were used as described above. Myofibrillar protein concentration was obtained by taking the difference between total and sarcoplasmic protein.

SDS Gel Electrophoresis

A muscle sample (2 g) was added to 20 mL of rigor-buffer containing 75 mM KCl, 10 mM KH_2PO_4 , 2 mM EGTA (pH 7.0), and homogenized with a polytron on the lowest setting using 3×4 s bursts. The homogenate was centrifuged at $10,000 \times g$ for 10 min at 4°C, and the supernatant (S1) was carefully decanted and saved. Twenty milliliters of rigor-buffer was added to the pellet and homogenized. A sample (0.5 mL) of this homogenate (P1) was saved, and centrifugation was repeated. This process was repeated to obtain S1 to S4 and P1 to P4. The S1 was used for sarcoplasmic fractions, whereas P4 was used for the myofibrillar fraction. The samples were mixed 1:1 with standard sample buffer which contained 8 M urea, 2 M thiourea, 3% (wt/vol) SDS, 75 mM DL-dithiothreitol, and 25 mM Tris-HCl at pH 6.8 (Fritz et al., 1989), and were then heated at 100°C for 3 min in a dry bath heater, cooled, and applied to the gel. For resolution of sarcoplasmic fractions, the resolving gel contained 15% acrylamide (wt/vol) and 0.075% bis-acrylamide (wt/vol), pH 8.8, and approximately 10 μg of protein was loaded per

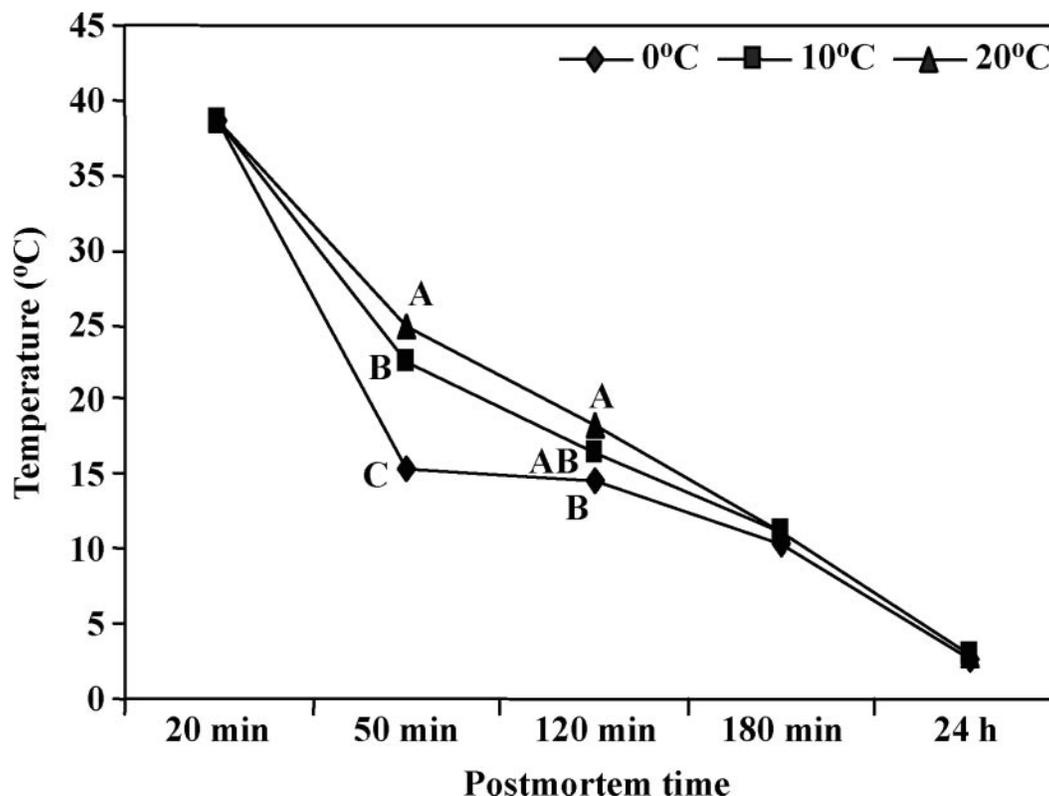


Figure 1. Temperature decline in duck carcasses that were chilled at 0, 10, or 20°C for 30 min postmortem.

lane. The reservoir buffer used in the Hoefer SE 250 Mighty Small electrophoresis unit (San Francisco, CA) contained 50 mM Tris, 0.384 M glycine, and 0.1% (wt/vol) SDS. The Mighty Small gels were run at a constant current of 20 mA per gel. The gels were stained at room temperature for 1 h in a solution containing 0.05% (wt/vol) Coomassie blue R-250 in 45% (vol/vol) methanol-9.2% (vol/vol) acetic acid and were destained by diffusion in 10% (vol/vol) methanol-7.5% (vol/vol) acetic acid.

Statistical Analysis

The experiment was repeated with 2 different trials with each trial considered as a replication. All the data for duck breast meat quality were subjected to one-way ANOVA as a completely randomized design, with chilled water temperature as the main effect, using the GLM procedure of SAS (SAS, 2002). Significant differences among the means were determined using Duncan's multiple range test (SAS, 2002).

RESULTS AND DISCUSSION

Carcass Temperature

The effects of chilling temperature on duck carcass temperature are shown in Figure 1. A significantly

lower ($P < 0.05$) carcass temperature was found in the 0°C chilled water when compared with the 10 and 20°C water treatments, at 50 and 120 min postmortem; however, no significant differences were found in carcass temperatures at 180 min and 24 h postmortem for the different chill water treatments. Alvarado and Sams (2004) found significantly higher temperatures in turkey breasts chilled at 30°C, at 60 and 120 min postmortem, than those chilled at 0, 10, and 20°C (45 min of chilling).

The pH of Breast Meat at Different Postmortem Periods

The postmortem pH did not differ ($P > 0.05$) among the treatments over 24 h, except for 50 min postmortem (Figure 2). The pH of the breast meat samples chilled in the 0°C water were higher ($P < 0.05$) at 50 min postmortem than the meat samples chilled at 20°C (just after chilling), although no significant differences were found between the breast meat samples treated at 0 and 10°C, and at 10 and 20°C ($P > 0.05$). These results indicated that the declining duck carcass temperature affected the pH of the breast meat at 50 min postmortem. Although differences ($P < 0.05$) were found in duck carcass temperatures at 120 min postmortem between 0 and 20°C chilled carcasses, pH differences were not as large as at 50 min postmortem, possibly due to smaller differences in carcass temperature.

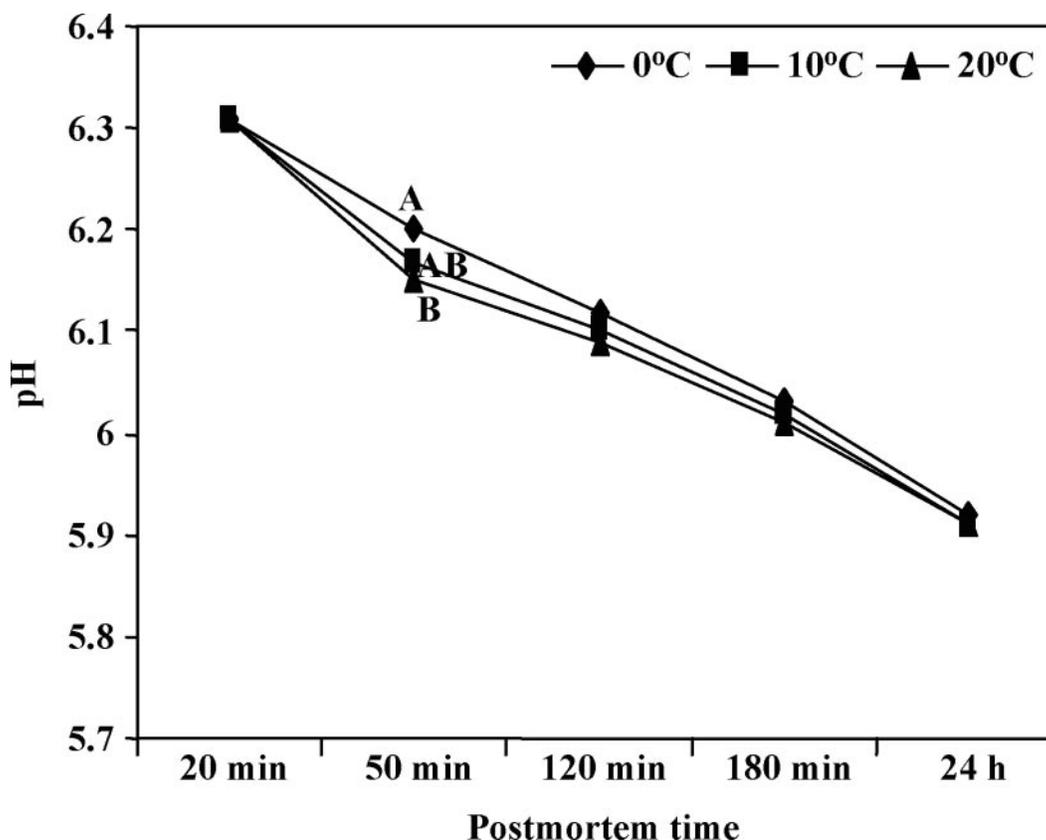


Figure 2. pH decline in duck carcasses that were chilled at 0, 10, or 20°C for 30 min postmortem.

Table 1. The meat quality parameters of duck breast from carcasses that were chilled at 0, 10, or 20°C for 30 min postmortem (means \pm SE)¹

Parameter	Chill water temperature (°C)			P
	0	10	20	
Drip loss (%)	1.81 \pm 0.03	1.70 \pm 0.05	1.81 \pm 0.05	NS ²
Cooking loss (%)	40.5 \pm 0.5	40.0 \pm 0.4	41.2 \pm 0.6	NS
Moisture content (%)	62.2 \pm 0.3	61.8 \pm 0.3	62.4 \pm 0.4	NS
L*	43.8 \pm 0.4 ^B	45.1 \pm 0.6 ^{AB}	46.4 \pm 0.5 ^A	**
a*	15.5 \pm 0.3 ^A	14.3 \pm 0.3 ^B	14.0 \pm 0.4 ^B	**
b*	5.36 \pm 0.21 ^A	4.57 \pm 0.21 ^B	5.54 \pm 0.28 ^A	*
Shear force (kg/cm ²)	3.74 \pm 0.05	3.66 \pm 0.06	3.70 \pm 0.05	NS
Sarcomere length (μ m)	1.84 \pm 0.03	1.88 \pm 0.03	1.85 \pm 0.02	NS
Sarcoplasmic protein (mg/g)	74.2 \pm 2.8	73.3 \pm 2.1	70.9 \pm 2.2	NS
Myofibrillar protein (mg/g)	107.4 \pm 2.6	109.4 \pm 2.9	107.7 \pm 1.7	NS
Total protein (mg/g)	182.2 \pm 2.4	182.7 \pm 2.9	178.6 \pm 1.9	NS

^{A,B}Means in each row with no common superscript differ significantly ($P < 0.05$).

¹Averages of 24 breasts in each chilling method.

²NS = not significant.

* $P < 0.05$; ** $P < 0.01$.

Drip Loss, Cooking Loss, and Moisture Content

No differences ($P > 0.05$) in drip loss, cooking loss, and moisture content existed among the treatments (Table 1). Alvarado and Sams (2004) found that cooking loss at 24 h postmortem was not affected when turkey carcasses were chilled at 0, 10, 20, and 30°C for 45 min before deboning at 60 min postmortem. In turkey thigh muscle, 0°C chilling resulted in greater drip loss than chilling at 12°C, yet even greater drip loss was observed at 30°C. In breast muscle, greater drip loss and lower homogenate cooking yields were observed at 30°C, whereas chilling at 0 and 12°C minimized water losses (Lesiak et al., 1996). The chilling temperatures in this experiment were lower than 30°C and did not cause differences in duck breast meat quality. Even though Dunn et al. (1995) and Lesiak et al. (1997) found strong correlations between pH_{24h} and cooking loss, no differences in cooking loss were found in our study, which might be related to the lack of significant pH_{24h} differences among the breast meat samples.

Instrumental Color

The effects of chill water temperature on duck breast meat color are shown in Table 1. Differences ($P < 0.05$) existed among meat samples for different chilling methods. Lightness (L*) was higher ($P < 0.05$) in the breast meat samples chilled at 20°C than the 0°C treatment. No significant differences were found in L* values between the 10 and 0°C, and 10 and 20°C chilled breast meat samples ($P > 0.05$). Redness (a*) was higher in the 0°C treatment when compared with the 10 and 20°C treatments. Yellowness was the lowest in 10°C samples, and no significant difference was found between the 0 and 20°C treatment samples.

Rathgeber et al. (1999) stated that turkey breast meat from delayed chilled carcasses was lighter (higher L*), redder (higher a*), and more yellow (b*) than

comparable samples from carcasses that were immediately chilled. In our results, significantly higher L* and b* values, but lower a* value, were found in the slow-chilled breast meat samples (20°C water) than in other treatments (0 and 10°C). McKee and Sams (1998) reported increased L* values for turkey breast meat held at 40°C for 2 h as compared with samples held at lower temperatures (20 and 0°C). Reasons for these changes in color with different chilling methods are unclear. Gigiél et al. (1989) and van der Wal et al. (1995) studied various chilling systems operating at different temperatures but failed to note any effects on meat color or water holding capacity in pork.

Shear Force and Sarcomere Length

The effects of chill water temperature on the shear force and sarcomere length of the duck breast meat are shown in Table 1. Neither shear force nor sarcomere length differed ($P < 0.05$) among the treatments. Dunn et al. (2000) found a strong negative correlation between shear force and sarcomere length in chicken breast meat, emphasizing that sarcomere shortening was a major contributor to toughness when the carcasses were chilled at -12 and 0°C. In another experiment by Dunn et al. (1995) on chicken breast meat, no differences were found in sarcomere length, although significant differences were found in shear force, when the chicken carcasses were chilled at 0°C for 23 h (A) and 10°C for 10 h, followed by 0°C for 13 h (B) and 10°C for 23 h (C); shear force values were highest in C and lowest in A ($P < 0.001$). They also found a weak negative relationship between shear force and sarcomere length. In our experiment, although no differences ($P > 0.05$) were found among the meat samples for sarcomere length and shear force, higher sarcomere values, and lower shear force values were found in the 10°C chilled breast meat samples, indicating a negative correlation.

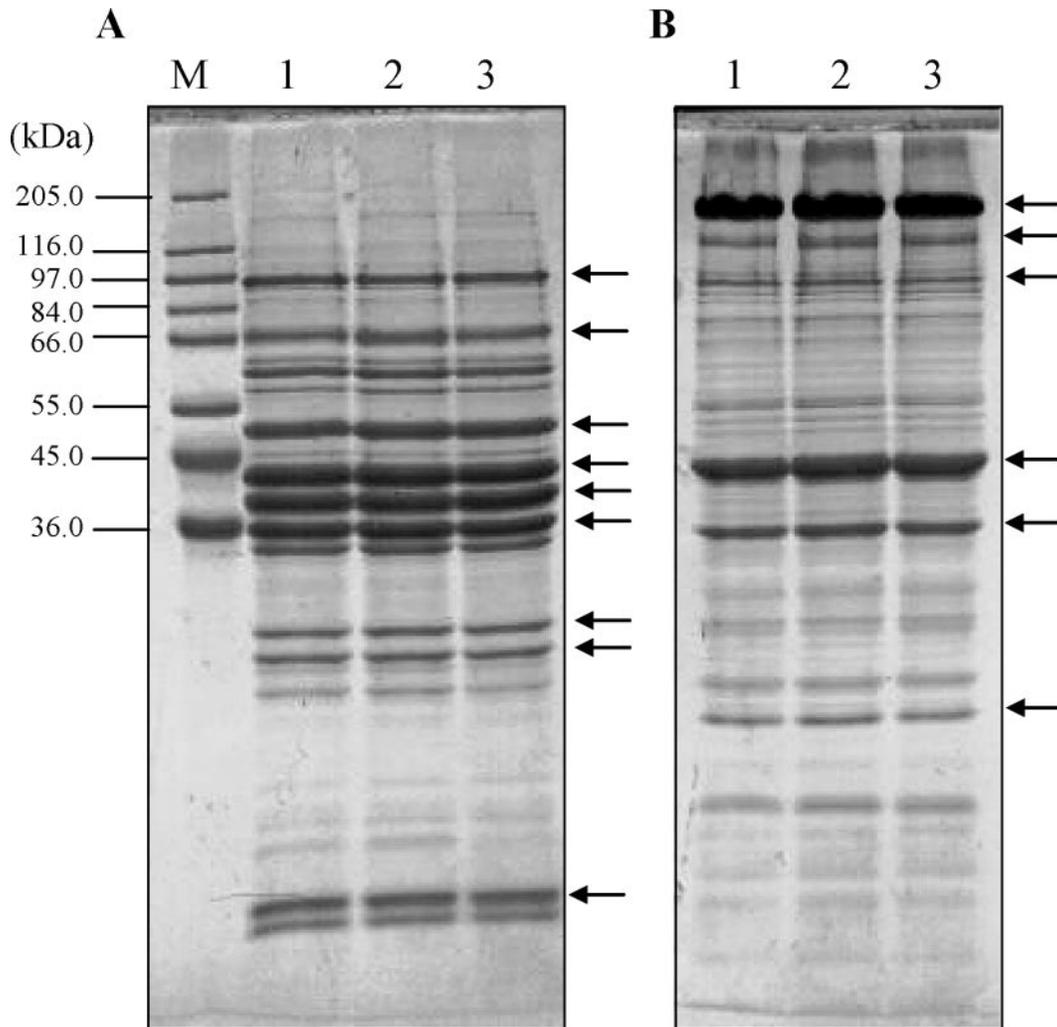


Figure 3. Sodium dodecyl sulfate-PAGE pattern of sarcoplasmic (A) and myofibrillar (B) proteins of duck breast meat from carcasses that were chilled at varying water temperatures (where 1 = 0°C, 2 = 10°C, 3 = 20°C). Arrows indicate the major protein bands. M denotes protein molecular mass standards.

Honikel et al. (1981) reported that when beef muscle strips were exposed to temperatures above 25°C or below 4°C, greater muscle shortening occurred and was found to be directly related to greater amounts of muscle drip loss. The muscle fiber type in duck breast is oxidative red fiber, whereas the red muscle of beef is slow oxidative red fiber (type I); therefore, the effect of cold shortening is lower in duck breast meat than in beef red muscle during chilling. However, duck carcasses are covered with a thick skin, and have sufficient fat layers under the skin, which may be responsible for reducing the chilling effect on muscle shortening at 0 and 20°C; it was previously shown that fat thickness can play a significant role in reducing cold shortening during the chilling of beef (Dolezal et al., 1982) and lamb (Smith et al., 1976). Again, cold shortening occurred in water-chilled excised strips of chicken breast muscle at 0°C (Dunn et al., 1993a,b), but did not occur in the breast muscles of whole birds carcasses chilled under similar conditions (Dunn et al., 1995). One reason might be that the breast muscles in whole bird

carcasses are restrained by their skeletal attachment and therefore are effectively prevented from excessive shortening. Whole bird carcasses cool much more slowly in water than excised strips of breast meat (Dunn et al., 1995). However, in our experiment we chilled whole duck carcasses, which might have protected them from cold shortening.

Protein Denaturation and Solubility

No significant differences were found in total protein, myofibrillar protein, and sarcoplasmic protein solubility among the breast meat samples (Table 1). Although increasing the rate of chilling leads to a more rapid temperature decline in carcasses and often to a slower pH decline (Jones et al., 1993; Milligan et al., 1998), chilling does not necessarily induce a significant decrease in protein denaturation. This may be due to the fact that chilling affects pH mainly in the early period postmortem (Long and Tarrant, 1990), which is similar to the results of the present study. Jones et al. (1993)

reported that blast-chilling did not decrease protein denaturation. Furthermore, Rathgeber et al. (1999) found positive correlations between pH at 24 h, and sarcoplasmic protein and myofibrillar protein extractability in turkey breast meat. Because no differences existed ($P > 0.05$) in our experiment for pH at 24 h, protein solubility should also not differ. Joo et al. (1999) found a relationship between protein solubility and protein denaturation by SDS-PAGE gel electrophoresis in pork muscles. They also found that PSE porcine muscles exhibit lower protein solubility compared with other quality classes, and the sarcoplasmic and myofibrillar samples distinctly showed associations of some sarcoplasmic proteins with the myofibrillar protein fractions in PSE meat during SDS-PAGE gel electrophoresis.

In our experiment, SDS-PAGE gel electrophoresis was performed to see the major protein bands visually. No differences were found in the major protein bands (Figure 3) among the 3 chilling methods.

In conclusion, carcasses within 0 to 20°C water temperatures did not create any variations in muscle shortening, tenderness, or protein denaturation in breast meat. However, the color values of the breast meat were affected by chill water temperatures. The 0°C chill water temperature improves color and does not induce cold shortening, so this temperature could be utilized to chill the whole duck carcass at duck processing plants.

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