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Quality of Duck Breast and Leg Meat after Chilling Carcasses in Water at 0, 10 or 20°C

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ABSTRACT : An experiment was carried out to investigate the effects of different chilling temperature on duck breast and leg meat quality. Duck carcasses were chilled for 30 minutes in water at either 0°C, 10°C or 20°C within 20 minutes of *post mortem* with 6 carcasses per group. Results showed no significant effects of chilling temperature on ultimate pH, protein solubility, sarcomere length and shear force value for duck breast or leg meat ($p>0.05$). Leg meat had higher ultimate pH, redness and shear force value, lower cooking loss, lightness, yellowness and protein solubility values than breast meat. The interaction of meat type and chilling temperature on cooking loss was significant ($p<0.05$). The effect of chilling temperature on cooking loss was more severe in leg meat than breast meat and 20°C chilling resulted in significantly higher cooking losses than the other chilling temperatures. Results of this experiment revealed that duck carcass can be chilled at 10°C without any harmful effect on meat quality including toughness of meat. (**Key Words :** Duck, Breast, Leg and Chilling Methods)

INTRODUCTION

Duck is still very popular in many areas of the world, especially in Asia. However, duck meat has received little attention by researchers compared to other poultry. More recently, duck cuts such as breast and legs have become more available, which offers more options for diet conscious consumers. Normally, the duck slaughtering procedure is like that for chickens, although duck muscle has more red muscle fibers compared to chicken (Smith et al., 1993). Muscle types vary in their potential to cold shorten, with red being more susceptible than white (Bendall, 1975). For beef and lamb, employing chilling parameters that minimize cold shortening is of the greatest importance and can be best addressed by ensuring muscle temperatures are not below 10°C before pH reaches 6.2. By comparison in pork, because of the effects of high muscle temperatures and low pH on the development of pale, soft and exudative (PSE) pork, a more rapid chilling process is needed to reduce PSE with the recommended internal muscle temperature of 10°C at 12 h and 2 to 4°C at 24 h (Savell et al., 2004). The relationship of cold shortening and sarcomere length was first demonstrated clearly by Herring et al. (1965) who showed the direct relationship of sarcomere length to fiber diameter and toughness. Rigor mortis in normal *post mortem* (PM) muscle develops at a faster rate in red fibers than in white fiber muscles, but chilling has a greater effect in slowing the rate of rigor mortis development in red fibers compared with white fibers (Sams and Janky, 1991).

Honikel et al. (1981) reported that when beef muscle was exposed to temperatures above 25°C or below 4°C, greater muscle shortening occurred and this was found to be directly related to greater amounts of muscle drip loss. In turkey thigh muscle, 0°C chilling resulted in greater drip loss than chilling at 12°C, but the greatest drip losses were observed at 30°C (Lesiak et al., 1996). Again, these authors stated that greater drip loss and lower homogenate cooking yields were observed for turkey breast muscle held at 30°C post-mortem, whereas 0 and 12°C minimized water losses.

Therefore, the present study was undertaken to investigate the effect of chilling temperature on duck breast and leg meat toughness and other meat quality parameters.

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MATERIALS AND METHODS

Eighteen ducks (Chungdong ori. *Anas platyrhynchos*) aged 48 days were slaughtered in a processing plant (Hadong, Korea) by a conventional neck cut and then scalded and eviscerated on a conveyer belt. Duck carcasses were harvested from the plant just before chilling at 20 min *post mortem*. Six carcasses each were chilled for 30 minutes in either ice water at 0°C, water at 10°C or water at 20°C. After chilling, carcasses were placed in a plastic box with ice and taken to the meat science laboratory of Gyeongsang National University where they were stored in a cold storage room at a temperature range of 2 to 4°C.

After 24 h breast and leg meat from 18 carcasses were removed from the carcasses and pH, cooking loss, CIE* color values, sarcomere length, shear force and protein solubility were measured as described below.

pH measurement

Samples (3 g) were homogenized using a poly-tron homogenizer (T25basic, IKA, Malaysia) with distilled water (27 ml) and pH then measured using a pH-meter (MP230, Mettler Toledo, Swiss).

Cooking loss

Breast and leg meat samples were broiled to a water bath temperature of 90°C for 30 min, surface dried and weighed. The final internal temperature of breast meat was around 75°C. Cooking loss was determined by expressing cooked sample weight as a percentage of precooked samples weight following the procedure of Yang et al. (2006).

Shear force

Shear force was measured using the Instron Universal Testing Machine (Model 3343). From each cooked meat sample, as close as practicable to a 5×40 mm (approximately 2.0 cm^2) cross section was cut for shear force measurement. The meat samples were placed at right angles to a plunger type blade. Crosshead speed was 100 mm/min and full scale load 50 kg. Ten samples were measured from each muscle type for each chilling temperature.

Color analysis

Immediately after deboning the surface color (CIE L*, a*, b*) of duck breast and leg meat samples was measured using a Minolta Chromameter (Minolta CR 301, Tokyo, Japan). Three random readings were taken from each meat type.

Sarcomere length

A sample of muscle (1-2 g) was 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 sample was transferred to a fresh vial containing solution B (0.25 M KCl, 0.29 M boric acid and 5 mM ethylenediaminetetraacetic acid in 2.5% glutaraldehyde) for 17-19 h. On the following day, individual fibers were teased from the muscle bundle 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 the screen that were perpendicular to the long axis of the fibers as described by Cross et al. (1981).

$$\text{Sarcomere length } (\mu m) = ((632.8\times10^{-3}\times D\times SQRT((T/D)^2+1))/T)\times100$$

Where, D equals distance (mm) from the specimen-holding device to the screen (D = 98 mm) and T equals the separation (mm) between the zero and the first maximum band.

Protein solubility

To determine the solubility of the sarcoplasmic and total (sarcoplasmic+myofibrillar) proteins, two 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 muscle samples (1 g). The samples were cut up with scissors, homogenized on ice with a Polytron (T25basic, IKA, Malaysia) on the lowest setting (3×4 seconds burst to minimize protein denaturation through heating), and then left on a shaker at 4°C overnight. Samples were centrifuged at 1,500 g for 20 min and the supernatant protein concentration was determined by the biuret method (Gornall et al., 1949). Total protein was extracted with 20 ml of ice-cold 1.1 M potassium iodide in 0.1 M phosphate buffer, pH 7.2 (Helander, 1961) which was added to duplicate samples (1 g). The same procedures for homogenization, shaking, centrifugation and protein determination were used as described above. Myofibrillar protein concentration was obtained by difference between total protein and sarcoplasmic protein.

Statistical analysis

To test the temperature effect and meat type effect simultaneously, the data were analysed using a mixed model. The model included the fixed effect of temperature, meat type and their interaction and the random effect of duck to account for the dependency of the measures from the same duck. The analysis was carried out using SAS MIXED procedure (SAS, 2002).

Table 1. pH, cooking loss (%), sarcomere length (μm) and shear force (kg/cm^2) of breast and leg meat of duck carcasses chilled at different temperatures

Traits	Meat type (M)			Chilling temperature (T)			
	Lsmean		Pooled SEM	Lsmean			Pooled SEM
	Breast	Leg		0°C	10°C	20°C	
pH	5.95^B	6.52^A	0.03	6.26	6.24	6.20	0.05
Cooking loss[1]	35.14^A	26.35^B	0.28	30.12^B	28.75^C	33.38^A	0.27
Sarcomere length	1.85	1.97	0.05	1.89	1.95	1.90	0.08
Shear force	3.16^B	3.49^A	0.08	3.40	3.23	3.34	0.09

[1] Cooking loss had a significant interaction ($p<0.05$) between meat type and chilling temperature. High chilling temperature in leg meat caused a severe effect.

[A-B] Lsmeans with different superscript are significantly different at $p<0.05$.

RESULTS AND DISCUSSION

pH of breast and leg meat

The chilling temperature did not affect the ultimate pH of duck breast and leg meat, although meat types varied in their ultimate pH values (Table 1). Absence of a significant effect of chilling on ultimate pH may be due to the fact that chilling affects pH mainly during the early *post mortem* period (Long and Tarrent, 1990). The pH of leg meat was significantly higher then breast meat, as shown by others (Mazanowski et al., 2003; Kisiel and Ksiazkiewicz, 2004).

Cooking loss

Results in Table 1 show that significant differences in cooking loss were found for different chilling temperatures and meat types ($p<0.05$). Again, the interaction of meat and chilling temperature was also significant ($p<0.05$). Although breast meat had a higher cooking loss than leg meat, chilling temperature had a greater effect on leg meat compared to breast meat and chilling at 20°C showed the highest cooking loss for both meat types. Significantly higher cooking losses at 20°C may be related to the pH and lightness of the two meats, although no significant differences were found in ultimate pH for different chilling methods. Petracci et al. (2004) determined that higher lightness is associated with lower ultimate pH and poorer water holding capacity in breast meat of broilers.

Alvarado and Sams (2004) found that cooking loss of breast meat at 24 h *post mortem* was not affected when broiler carcasses were chilled at 0, 10, 20 and 30°C for 45 min. However, our results which found significant differences in cooking losses of meat chilled at 20°C may be related to the muscle types of different species. Duck breast meat is composed of 70 to 90% oxidative red fibers (Type IIA) (Baeza, 1995), whereas chicken breast meat is almost entirely Type IIB (white) (Smith and Flether, 1992). In turkey thigh muscle, 0°C chilling resulted in greater drip loss than chilling at 12°C, but the greatest drip losses were observed at 30°C. Greater drip loss and lower homogenate cooking yields were observed for turkey breast muscle held at 30°C *post mortem*, whereas 0 and 12°C minimized water losses (Lesiak et al., 1996). These results indicate that chilling affects leg meat more severely than breast meat in different temperatures, which agrees with our results in duck meat. However, the average cooking loss in this experiment in duck breast meat was 35.14%, which was similar to that found by Ali et al. (2007) who reported 34.5% cooking loss of duck breast 24 h *post mortem*.

Shear force and sarcomere length

The different chilling temperatures and meat types did not affect the sarcomere length of meat samples ($p>0.05$). As expected from these results, the shear force values did not show significant differences for the three chilling temperatures. However, significant differences were found in shear force value between meat types and the shear force value of leg meat was higher than breast meat ($p<0.05$). This result revealed that shear force value of different meat types did not relate only to sarcomere length, and might be related to many factors like composition of meat, muscle fiber type etc. However, Dunn et al. (2000) found a strong negative correlation between shear force and sarcomere length, emphasizing that sarcomere shortening was a major contributor of toughness when carcasses were chilled at -12°C and 0°C. Again in breast meat, no significant differences were found in sarcomere length, although, significant differences were found in shear force in another experiment of Dunn et al. (1995) with chicken carcasses chilled at 0°C for 23 h (A), 10°C for 10 h followed by 0°C for 13 h (B) and 10°C for 23 h (C) and shear force value was 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, no significant differences were found among meat samples at different chilling temperatures in sarcomere length and shear force, the higher sarcomere value and lower shear force value which were found at 10°C in both breast and leg meat samples indicates a negative correlation.

Honikel et al. (1981) reported that when beef muscle was 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.

Table 2. CIE* color (L*, a*, b*) values of breast and leg meat of duck carcasses chilled at different temperatures

Traits	Meat type (M)			Chilling temperature (T)			
	Lsmean		Pooled SEM	Lsmean			Pooled SEM
	Breast	Leg		0°C	10°C	20°C	
Lightness	44.52^{A}	42.77^{B}	0.63	40.68^{C}	43.68^{B}	46.57^{A}	0.93
Redness	12.50^{B}	15.12^{A}	0.77	15.35^{A}	13.17^{B}	12.91^{C}	0.69
Yellowness	6.30^{A}	4.39^{B}	0.56	5.62	4.32	6.10	0.89

$^{A-B}$ Lsmeans with different superscript are significantly different at $p<0.05$.

Table 3. Different protein solubility (mg/g) values of breast and leg meat of duck carcasses chilled at different temperatures

Traits	Meat type (M)			Chilling temperature (T)			
	Lsmean		Pooled SEM	Lsmean			Pooled SEM
	Breast	Leg		0°C	10°C	20°C	
Sarcoplasmic protein	70.61^{A}	62.27^{B}	1.37	64.90	69.65	64.77	1.98
Myofibrillar protein	113.72^{A}	103.99^{B}	1.39	109.51	107.10	109.96	1.67
Total protein	184.32^{A}	166.26^{B}	1.14	174.41	176.75	174.72	1.49

$^{A-B}$ Lsmeans with different superscript are significantly different at $p<0.05$.

Duck carcass is covered with thick skin and enough fat layers under the skin, therefore, might be responsible for reducing the chilling effect at 0°C and 20°C on muscle shortening, as fat thickness can play a significant role in the reduction of cold shortening during the chilling process of beef (Dolezal et al., 1982) and lamb (Smith et al., 1976). Again, cold shortening was caused by water chilling excised strips of chicken breast muscle at 0°C (Dunn et al., 1993a,b) but did not appear to occur in the breast muscles of whole bird carcasses chilled under similar conditions (Dunn et al., 1995). The explanation might be that muscles in whole bird carcasses are restrained by their skeletal attachment and are, therefore, effectively prevented from excessive shortening. Furthermore, the whole bird carcasses cool much more slowly in water than excised strips of breast meat (Dunn et al., 1995). However, in our experiment the whole duck carcasses were chilled, which might protect the carcasses from cold shortening in leg and breast meat.

Color value

The results of CIE* (L*, a* and b*) color values are presented in Table 2. Significant differences for different chilling temperatures and meat types were found in lightness (L*), although no significant effect was found for the interaction of chilling temperature and type of meat. It was shown that with increasing chilling water temperature the lightness decreased. The L* value of duck breast was significantly higher than leg meat. Redness (a*) value also showed significant differences for different chilling temperatures and meat types, although their interaction was not significant. The a* value decreased with increasing chilling water temperature and leg meat had a higher a* value than breast meat. The yellowness (b*) value did not show significant differences for chilling temperature although significant differences were found for meat types. The yellowness value was higher in breast meat compared to leg meat.

McKee and Sams (1998) reported increased L* values for turkey breast meat held at 40°C for 2 h compared to samples held at lower temperatures (20 and 0°C). Rathgeber et al. (1999) stated that turkey breast meat from delayed chilled carcasses was significantly lighter (higher L*), redder (higher a*) and more yellow (higher b*) than comparable samples from carcasses chilled immediately. In our results, a significantly higher L* value was found in slow chilled breast meat (20°C). Again, b* value did not show significant differences ($p>0.05$) at different chilling temperature, however, the value was higher at 20°C. Contradictory to the previous results, the a* value was significantly lower in our experiment than other treatments (0°C and 10°C). Reasons for these changes in color with different chilling temperatures are unclear. However, Gigiel et al. (1989) and van der Wal et al. (1995) studied various chilling systems operating at different temperatures and failed to note any effects on meat color or water holding capacity in pork.

Protein solubility

Sarcoplasmic, myofibrillar and total protein solubility did not show significant differences for the three chilling temperatures; however, significant differences in sarcoplasmic, myofibrillar and total protein solubility were found between breast and leg meat of ducks ($p<0.05$). In all cases, higher protein solubility values were found in breast meat. Although increasing the rate of chilling leads to a more rapid temperature decline in the carcass 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 *post mortem* period (Long and Tarrent, 1990). Jones et al. (1993) reported that blast-chilling did not decrease protein denaturation. Rathgeber et al. (1999) found a positive correlation between ultimate pH and sarcoplasmic and myofibrillar protein

extractability in turkey breast meat. No significant differences in ultimate pH were found in our experiment. therefore, protein solubility did not show any differences with chilling temperature. Again the higher protein solubility in breast meat may be related to the higher protein content of duck breast meat compared to leg meat. Işgurer et al. (2002) and Mazanowski et al. (2003) found a higher protein content in breast meat compared to leg meat in ducks.

CONCLUSION

Results from this research indicate that duck chilling during processing is possible at 10°C without any problem of toughening the meat. The chilling temperature severely affects the color values of meat with higher temperatures causing increased lightness and decreased redness. Cooking loss was significantly higher at 0°C and 20°C compared to 10°C. These results suggested that it is possible to chill duck carcasses in processing plants at 10°C.

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