

Comparison of Physicochemical Characteristics of Hot-boned Chicken Breast and Leg Muscles during Storage at 20°C

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Abstract

The aim of this study was to compare the physicochemical changes of hot-boned chicken breast and leg muscles. Chicken breast and leg muscles from 56 broilers were excised within a 15 min post-mortem (PM) and stored at 20°C. Physicochemical traits were determined at 0.5, 6, 12, and 24 h PM. The ultimate pH of leg muscle was higher than that of breast muscle ($p < 0.05$). The content of glycogen in the breast muscle was relatively higher than that in the leg muscle until 6 h PM ($p < 0.05$). R-values showing rigor mortis of breast and leg muscles were completed after or before 6 h PM. Breast muscle had less cooking loss than leg muscle ($p < 0.05$). Drip loss did not significantly differ between breast and leg muscles with the exception of that at 6 h PM. The sarcomere length of leg muscle was relatively longer than that of breast muscle ($p < 0.05$). The MFI of leg muscle was significantly lower than that of breast muscle ($p < 0.05$). The shear force of leg muscle was lower than that of breast muscle at 6 and 12 h PM ($p < 0.05$); however, that of both muscles did not significantly differ at 24 h PM.

Key words: broiler chicken, hot-boning, sarcomere length, myofibrillar fragmentation index, meat tenderness

Introduction

The marketing of chicken parts is one of the fastest growing segments of the food industry worldwide. Special interest in this field is partially due to the convenience and nutritional value of cuts such as chicken breasts and thighs (Seabra *et al.*, 2001). The breast muscle of chicken meat contains greater levels of white fibres, whereas the leg muscle of chicken meat contains higher levels of red fibres. Generally, red muscle contains more water and fat and less protein than white muscle and has a higher final pH (Chang and Chou, 2010; Vega-Warner *et al.*, 1999). Moreover, white muscle contains more glycolytic enzymes, which can stimulate a rapid reaction, speed up the decline in pH, and accelerate rigor

mortis in meat (Farouk and Lovatt, 2000). Geesink *et al.* (1995) reported that the decrease in pH is related not only to a variety of myofibrils but also to a decrease in muscle temperature, because pH decline was faster in the *M. triceps brachii* than that in *M. longissimus dorsi*, whereas the slower temperature decline in *M. triceps brachii*.

Many studies have been conducted to investigate the physicochemical characteristics and meat quality of chicken breast and leg muscles. Chang and Chou (2010) and Yu *et al.* (2005) reported that the pH values of breast muscles were lower ($p < 0.05$) than those of leg and thigh muscles. Lesiów and Xiong (2003) compared the influence of muscle fibre types on gelation. They observed that the optimal gelling pH for breast muscle homogenates (pH 6.3) was slightly higher than that for thigh muscle homogenates (pH 5.8-6.3). Nowsad *et al.* (2000) determined the collagen content of broiler breast and thigh mince, which showed that the collagen content of broiler breast (3.9 mg/g) was lower than in thigh (9.3 mg/g). Liu and Xiong (1996) reported no significant difference ($p > 0.05$) in TBARS

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content between breast and leg muscle myofibril samples. However, little information is available to the comparison to physicochemical characteristics of hot-boned chicken breast and leg muscles after slaughter in 24 h.

One method used to improve the efficiency of chicken meat processing is the immediate removal of poultry meat from the carcasses after slaughter, which is known as "hot-boning" (Hamm, 1983; Lyon *et al.*, 1985). Changing from conventional cold-boning poultry processing to hot-boning methods has gained much interest because of potential savings in labor, space, and energy requirements (Lyon and Hamm, 1986). The process of hot-boning involves removal of muscle from the bone while it is at, or near, body temperature. However, hot-boning adversely affects the texture and juiciness of fillets and breaded chicken portions (Seabra *et al.*, 2001) and increases muscle toughness, which is due to muscle shortening (Lesiak *et al.*, 1996). An increased emphasis has been placed on the research of these meat characteristics, and various methods have been investigated to overcome the toughness associated with hot-boning (Cason *et al.*, 2002; Hamm, 1983; Lyon and Hamm, 1986).

Post-mortem (PM) temperature was noted to be the most important processing factor affecting rigor mortis development and overall meat quality (Lee *et al.*, 1979). De Fremery and Pool (1960) showed a rapid rate of PM glycolysis and the early onset of rigor mortis in birds exposed to PM temperatures of 37 to 41°C during processing. Temperatures ranging from 10 to 25°C have been found to have no effect on poultry meat tenderness (Khan, 1971). Therefore, the current experiment was conducted to compare the physicochemical characteristics and meat quality of hot-boned chicken breast and leg muscles during post mortem storage stored at 20°C.

Materials and Methods

Muscle sample preparation

Fifty-six commercially reared broiler chickens (6 wk of age with a live weight of approximately 1.5-2.0 kg) from a local poultry processor were transported to the Meat Science Laboratory in Konkuk University and held overnight to minimize the effects of catching and handling. The birds were stunned electrically at 50 V for 10 s and killed by bleeding for approximately 2 min from a single unilateral neck cut severing the right carotid artery and jugular vein (Yu *et al.*, 2005). Immediately after bleeding and after the skin was peeled off, the breast and leg muscles from the left and right side of the carcasses were

excised within 15 min PM and the samples were randomly cut into 4 portions, respectively. The first portion (breast and leg) was used to determine physicochemical characteristics within 30 min after slaughter. The remaining portions were packed separately in polyethylene bags (FoodSaver[®]; CSE, Korea) and stored at 20°C until 24 h PM. The physicochemical properties of these 3 portions were evaluated at 6, 12, and 24 h PM, respectively.

pH, R-value, and glycogen content

The pH of the muscle samples were determined in triplicate using a modification of the iodoacetate method initially described by Jeacocke (1977). Approximately 2 g of sample were homogenized in 10 mL of an iodoacetate solution (5 mM sodium iodoacetate, 150 mM potassium chloride; pH adjusted to 7.0 with potassium hydroxide) using an Ultra Turrax (Model No.T25; Janken and Kunkel, Germany) at 10,000 rpm for 1 min; the pH of the homogenate was determined using a pH meter (340; Mettler Toledo GmbH, Switzerland).

The R-value was determined using a modification of a method initially described Koh *et al.* (1993). 4 g of sample were homogenized in 6% perchloric acid (HClO₄) at 5,000 rpm for 90 s, the solution was centrifuged at 3,000 g for 10 min, 10 mL of the supernatant was collected, the pH was adjusted to 6.0-6.5 with 2 M KOH, and the solution was chill-stored for 60 min. Thereafter, the solution was filtrated using a Whatman No. 1 filter paper, and 0.1 mL of the filtrated solution was mixed with 2.9 mL of 0.1 M phosphate buffer (pH 6.5). Absorbance at 250 and 260 nm was determined with a UV spectrophotometer (DU650; Beckman, USA). Then, the R-value of A_{250}/A_{260} was calculated.

The muscle glycogen content was measured as described by Dreiling *et al.* (1987), with minor modifications. Approximately 2 g of muscle were homogenized (Model No. T25; Janken and Kunkel, Germany) for 1 min in 20 mL of 9% perchloric acid and then centrifuged (SCR20BA; Hitachi, Japan) at 15,000 g for 20 min at 2°C. The supernatant was filtered and mixed with an iodine color reagent (0.26 g of potassium iodide in 10 mL distilled water and 100 mL saturated CaCl₂), and the absorbance at 460 nm was measured using a spectrophotometer (DU650; Beckman, USA).

Drip loss and cooking loss

Drip losses from the samples stored at 20°C for 24 h were determined by calculation of weight loss percentage compared with weight before storage. After drip loss

determination, the samples were bagged with polyethylene bags (Food Saver[®], CSE, Korea), immersed in a 75°C water bath (Model 10-101, Dae Han Co, Korea) for 30 min and cooled at room temperature for 30 min as described by Yu *et al.* (2008). After cooling to room temperature, the bags were opened, and the free juice was drained. The cooked samples were blotted with a paper towel and weighed. Cooking loss was measured by weighing the meat before and after cooking.

Sarcomere length

Sarcomere length was determined by the method (Voyle, 1971) with Helium-Neon-Laser diffraction (spectra-physics, Model No.212-2, USA). At different time of PM, 1-2 g of muscle samples were carefully cut with a knife and immersed in 2% glutaraldehyde solution with 2% glucose in a 0.1 M phosphate buffer (pH 7.0) of similar temperatures as those at which the muscles were incubated, and sarcomere length was measured.

Myofibrillar fragmentation index (MFI)

Myofibrils were obtained according to the method of Olson *et al.* (1976). 4 g of sample were put into homogenizer with 40 mL of 2°C MFI buffer (20 mM K₂HPO₄/KH₂PO₄, pH 7, 100 mM KCl, 1 mM EDTA, 1 mM NaN₃), and homogenized at 10,000 rpm for 30 s, then centrifuged at 1,000 g for 10 min. The supernatant liquid was removed and added 5 v/w separation media to suspend the sedimentation matter, and then centrifuged again just like above. After repetitions of above operation, the sedimentation matter was suspended with 5 v/w MFI buffer. Its connective tissue was filtrated with 18 mesh screens, and then the liquid collected was centrifuged with 3 repetitions of the former procedure. Ultimately, the sedimentation matter was suspended in MFI buffer, and the protein concentration of suspension was determined by the biuret method (Cooper, 1977). The myofibrils were suspended in MFI buffer. An aliquot of myofibril suspension was diluted with the MFI buffer to 0.5 mg/mL protein concentration and the absorbance of this suspension measured at 540 nm. MFI values were recorded as absorbance units per 0.5 mg/mL myofibril protein concentration multiplied by 200.

Myofibrillar Fragmentation Index (MFI)

= O.D. at 540 nm × 200

Warner-Bratzler shear force

For determining Warner-Bratzler shear force, samples

were cooked individually in plastic bags and immersed in a 75°C water bath for 30 min. The cooked meats were cooled and sampled at room temperature using a 12.7 mm circular bore to determine shear force. Four sample cores from each sample were sheared across the length of the core with a Warner-Bratzler shear attachment on the Texture analyser (TA-XT2i, Stable Micro Systems, England) and installed with blade set under cross head speed 2 mm/s. Texture Expert for the WINDOWS operation system was used to analyze the data. The shear force value was the mean of the maximum forces required to shear each set of core samples and the units used for shear force were Newtons (N).

Statistical analysis

The Statistical Analysis System (SAS, 1996) was used to calculate means, standard errors and analysis of variance. One-way variance analysis (ANOVA) was performed to compare the effects of storage times on the parameters of samples analyzed immediately after slaughter, and the means test using Dunnett's tests at a 5% level of significance. Additionally, the analysis of variance was performed by measuring the effects between breast and gel muscles using the minimum square method, and the means were compared using the Student *t* test ($p < 0.05$).

Results and Discussion

pH, R-value, and glycogen content

During storage at 20°C, chicken breast and leg muscles exhibited great differences in changes of pH, R-value and glycogen content (Table 1). pH values of breast muscle were significantly decreased from 6.32 at 0.5 h PM to 5.82 after 6 h PM, whereas there were no significant differences among at 6, 12, and 24 h PM in general agreement with previous study (Stewart and Fletcher, 1984) where reported decreases in pH values tended to level off at 5.9 after 4 h or before. Early studies by De Fremery and Pool (1960) revealed that the rigor mortis of chicken muscle was completed at 6 h before PM and achieved ultimate pH. In addition, pH of leg muscle significantly decreased from 6.29 at 0.5 h PM to 6.18 after 6 h PM. And pH values of leg muscle at 6, 12, and 24 h were significantly greater than those of breast muscle ($p < 0.05$). Normally, a decline in pH is related to the accumulation of lactic acid in the muscle during PM glycolysis (Lawrie, 1991). The results of the current study indicate that the pH of breast muscle, which contains a greater proportion of white fibrils, declined more rapidly than that of leg

Table 1. Changes in pH, R-values, and glycogen contents (mg/g tissue) in hot-boned chicken breast and leg muscles during storage at 20°C

Traits		Postmortem time (h)			
		0.5	6	12	24
pH	Breast	6.32 ^a ±0.06	5.82 ^{b,y} ±0.04	5.71 ^{b,y} ±0.03	5.73 ^{b,y} ±0.02
	Leg	6.29 ^a ±0.03	6.18 ^{b,x} ±0.04	6.15 ^{b,x} ±0.04	6.15 ^{b,x} ±0.04
Glycogen (mg/g)	Breast	3.25 ^{a,x} ±0.10	1.01 ^{b,x} ±0.03	0.74 ^c ±0.03	0.72 ^c ±0.03
	Leg	1.28 ^{a,y} ±0.04	0.81 ^{b,y} ±0.02	0.78 ^b ±0.02	0.77 ^b ±0.03
R-value	Breast	0.97 ^b ±0.03	1.26 ^a ±0.02	1.27 ^a ±0.01	1.28 ^a ±0.01
	Leg	1.01 ^c ±0.02	1.23 ^b ±0.01	1.24 ^b ±0.01	1.29 ^a ±0.01

Values are means±SE.

^{a-c}Means in the same row with different letters are significantly different ($p<0.05$).

^{x,y}Means in the same column with different letters are significantly different ($p<0.05$).

muscle. This result agrees with a previous study by Farouk and Lovatt (2000), who reported that white muscle fibres have a higher rate of glycolytic change than do red fibres and thus have a faster rate of pH decline. Lesiak *et al.* (1996) and Northcutt *et al.* (1994) reported in poultry meat, pH of leg muscle was higher than that of breast muscle about 0.2-0.3 unit. Also, Wattanachant *et al.* (2004) and Choe *et al.* (2010) stated pH of broiler thigh muscle was higher than that of breast muscle.

The R-value is an indirect measure of ATP depletion in the muscle (Mckee and Sams, 1998). During the development of rigor mortis, ATP in the muscle is depleted and the R-value increases because it represents the ratio of inosine- to adenosine-containing compounds in the muscle (Calkins *et al.*, 1982). In the current experiment, R-values of the breast muscle were 0.97, 1.01, 1.26, and 1.23 at 0.5, 6, 12, and 24 h PM, respectively. R-values of the leg muscle were 1.27, 1.24, 1.28, and 1.29 at 0.5, 6, 12, and 24 h PM, respectively. The R-values of the breast and leg muscles were not significantly different ($p>0.05$). The R-values of the breast and leg muscles were greater than 1.2 after 6 h PM, which indicated that rigor mortis was complete. Previous research has shown that the R-values of breast muscle reach values of 0.95-0.97 within 15-30 min PM and of 1.2-1.3 within 2-4 h PM; ultimate R-values were 1.35 (Papa and Fletcher, 1988; Young and Lyon, 1997).

The glycogen content in breast and leg muscles decreased sharply until 6 h PM ($p<0.05$) and decreased slowly thereafter. The glycogen content was relatively greater in breast muscle than in leg muscle until 6 h PM ($p<0.05$). This finding was similar to that of a previous study conducted by Mckee and Sams (1998), which showed that the glycogen content of *Pectoralis* muscle from turkey stored at a temperature of 20°C decreased sharply until 30

min PM and then decreased slowly thereafter. Fernandez *et al.* (1995) observed that fast-twitch glycolytic fibres of the *Longissimus lumborum* [composed predominantly of fast-twitch (89%) and white (77.3%) fibres] had a significantly greater glycogen content than did red (fast- and slow-twitch) fibres, whereas slow-twitch fibres of the *Semispinalis capitis* [composed mainly of red (61.1%) and fast-twitch (59.3%) fibres] had a significantly lower glycogen content than did fast-twitch (red and white) fibres. The current study showed that the glycogen content of breast muscle was greater than that of leg muscle, and breast muscle had a faster rate of pH decline and a lower ultimate pH than did leg muscle.

Drip loss and cooking loss

In the current experiment, water holding capacity was determined on the basis of drip loss and cooking loss. Drip loss in both breast and leg muscles increased as the storage period increased, and significant differences were observed between 6 and 24 h PM ($p<0.05$) (Table 2). However, no significant difference in drip loss was observed between the breast and leg muscles, except at 0.5 h PM. Cooking losses in breast muscle were not significantly different between the time periods evaluated ($p>0.05$) (Table 2). In leg muscle, however, significant differences in cooking loss were observed between 0.5 h and 6 h PM ($p<0.05$) but not between 6, 12, and 24 h PM ($p>0.05$). In addition, cooking loss in leg muscle was significantly greater than that in breast muscle during the storage period. These results are in agreement with those reported by Lesiak *et al.* (1996), who showed that drip loss in both the breast and thigh muscles of turkey meat increased with time at 0, 12, and 30 h PM temperatures. They also reported that drip loss in thigh muscle was less than that in breast muscle at all temperatures and storage

Table 2. Changes in cooking loss and drip loss in hot-boned chicken breast and leg muscles during storage at 20°C

Traits		Postmortem time (h)			
		0.5	6	12	24
Drip loss (%)	Breast	-	0.65 ^{b,x} ±0.03	0.72 ^{ab} ±0.03	0.77 ^a ±0.04
	Leg	-	0.54 ^{b,y} ±0.02	0.63 ^{ab} ±0.03	0.72 ^a ±0.04
Cooking loss (%)	Breast	15.54 ^y ±0.42	16.67 ^y ±0.39	16.01 ^y ±0.43	16.40 ^y ±0.56
	Leg	26.08 ^{a,x} ±0.60	18.45 ^{b,x} ±0.35	18.77 ^{b,x} ±0.47	19.52 ^{b,x} ±0.36

Values are means±SE.

^{a-c}Means in the same row with different letters are significantly different ($p<0.05$).

^{x,y}Means in the same column with different letters are significantly different ($p<0.05$).

times evaluated. Northcutt *et al.* (1994) also reported that leg meat generally has a lower drip loss and a greater water holding capacity than does breast meat, but cooked leg meat had a lower water holding capacity. Treatment and meat type were significant ($p<0.05$) determinants of drip loss and cooking loss. In addition, Botka-Petrak *et al.* (2005) reported that white muscle (*M. pectoralis superficialis*) has a greater water holding capacity than does red muscle (*M. iliotibialis lateralis*). Wyche and Goodwin (1974) reported that the heat yield of breast meat from broilers was greater than that of leg meat.

Sarcomere lengths, myofibrillar fragmentation index (MFI) and shear force

Sarcomere length in breast and leg muscles was longest immediately after slaughter ($p<0.05$), but no significant changes occurred after 6 h PM (Fig. 1). In addition, sarcomere length in leg muscle was longer than that in breast muscle ($p<0.05$). This result is consistent with that of Beecher *et al.* (1965), which indicates that red muscles (>40% red fibers) generally have a longer post-rigor sarcomere length than do white muscles (<30% red fibers).

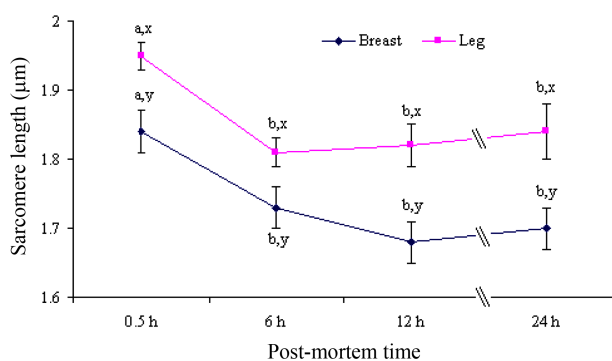


Fig. 1. Changes in sarcomere length (μm) in hot-boned chicken breast and leg muscles during storage at 20°C. ^{a,b}Means with different letters are significantly different from each other ($p<0.05$). ^{x,y}Means at the same time with different letters are significantly different ($p<0.05$).

Papa and Fletcher (1988) reported that reduced sarcomere lengths resulted in increased shear force in broiler breast muscle.

In the current study, tenderness was expressed by measuring the myofibrillar fragmentation index (MFI) and shear force values. The MFI of both breast and leg muscles increased during the storage period (Fig. 2). In breast muscle, no significant difference was found between 12 and 24 h PM; in contrast, a significant difference was found in leg muscle ($p<0.05$). Kim *et al.* (1996) reported that the MFI increased slightly until 6 h PM, regardless of treatment; however, the MFI increased rapidly by 12 h PM, reaching a value as high as 90%. In addition, the MFI of leg muscle was significantly lower than that of breast muscle during storage at 20°C ($p<0.05$). These phenomena were probably caused by differences in protein components between breast and leg muscles. Daum-Thunberg, *et al.* (1992) reported that breast meat had a greater percentage of extractable protein than did thigh meat. Moreover, meat tenderization correlated with the extent of structural protein degradation (Hopkins and Thompson, 2002).

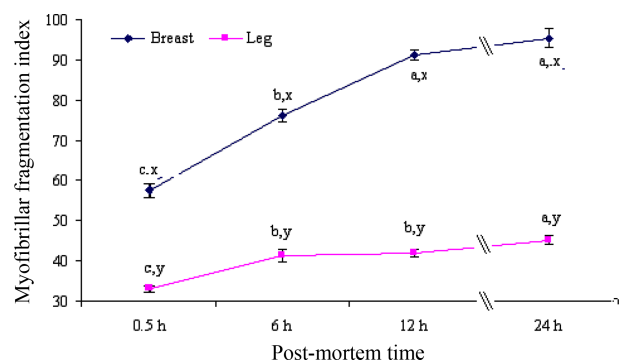


Fig. 2. Changes in the myofibrillar fragmentation index (MFI) in hot-boned chicken breast and leg muscles during storage at 20°C. ^{a-c}Means with different letters are significantly different from one another ($p<0.05$). ^{x,y}Means at the same time with different letters are significantly different ($p<0.05$).

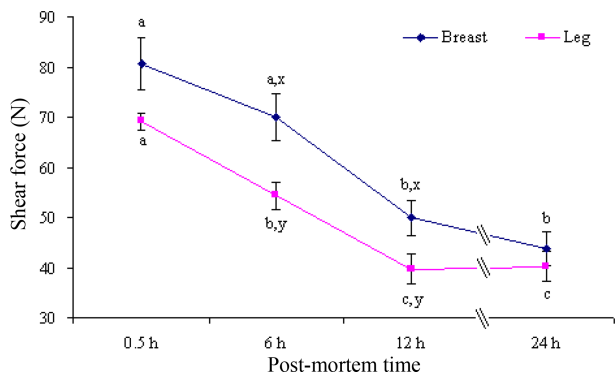


Fig. 3. Changes in Warner-Bratzler shear force (N) in hot-boned chicken breast and leg muscles during storage at 20°C. ^{a-c}Means with different letters are significantly different from one another ($p < 0.05$). ^{x,y}Means at the same time with different letters are significantly different ($p < 0.05$).

The shear force of both breast and leg muscles decreased over 24 h PM (Fig. 3). In breast muscles, shear force was not significantly different between 0.5 PM and 6, 12 and 24 h PM ($p > 0.05$), respectively. In leg muscles, there were significant differences between 0.5, 6, and 12 h PM, but not between 12 and 24 h PM. Overall, the shear force of leg muscle was lower than that of breast muscle. This result was slightly different from that of a previous study by Wattanachant *et al.* (2004), in which no differences in shear values were observed between the *M. biceps femoris* and the *M. pectoralis* muscle after they were cooked. However, Liu *et al.* (1996) observed that the *M. biceps femoris* muscle was the toughest and the *M. pectoralis* muscle was the most tender chicken muscle. These differences might have been due to different experimental designs.

Generally, a negative correlation has been found between the MFI and shear force (Kandeepan *et al.*, 2009; Olson *et al.*, 1976; Prado and de Felício, 2010; Toohey *et al.*, 2008). However in the current study, the MFI of breast muscle was significantly greater than that of leg muscle during the storage period. Shear force was significantly lower in leg muscle than in breast muscle at 6 and 12 h PM; however, shear force was not significantly different between leg and breast muscles at 24 h PM. These different results might due to different experimental material and designs. Kandeepan *et al.* (2009) and Lametsch *et al.* (2007) reported that the MFI and shear force showed low correlation. Purchas *et al.* (2010) indicated the tenderness was correlative with amount of intramuscular fat and sarcomere length.

Consequently, these above results implied the FMI and sarcomere was not suitable to be used as the index of

comparing tenderness between chicken breast and leg muscle.

In this study, hot-boning showed important effects on post-mortem physicochemical characteristics of chicken breast and leg muscles during storage at 20°C. The findings indicate that the glycogen content, water holding capacity, and shear force of breast muscle were higher than those of leg muscle. Early in the PM period, the MFI of breast muscle increased rapidly until 12 h, hereafter, increased only slightly. The MFI of leg muscle increased rapidly until 6 h PM and after 12 h PM; however, it increased only slightly between 6 and 12 h PM. The ultimate pH of leg muscle was higher than that of breast muscle, whereas the sarcomere length of leg muscle was longer than that of breast muscle. No significant difference in shear force was found between breast and leg muscles stored at 20°C at 24 h PM. These results demonstrated that hot-boning chicken breast and leg muscle had different post-mortem physicochemical properties.

Acknowledgements

This study was supported by Technology Development Program (608001-05-1-SB410) for Agriculture and Forestry, Ministry for Agriculture, Forestry and Fisheries, Republic of Korea. The authors also partially supported by the Brain Korean 21 (BK21) Project from Ministry of Education and Human Resources Development.

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(Received 2011.5.20/Revised 2011.8.31/Accepted 2011.9.19)