

## Effects of Hot Boning and Soy Sauce on the Processing Properties of Semi-dried Beef Jerky

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### Abstract

The objective of this study was to examine the effect of hot-boning and soy sauce as a curing agent on the processing properties of beef jerky. Beef jerky was prepared under the following four treatment conditions; Beef jerky with cold-boned beef and salt solution, beef jerky with cold-boned beef and soy sauce solution, beef jerky with hot-boned beef and salt solution, and beef jerky with hot-boned beef and soy sauce solution. Cured meat and jerky containing hot-boned beef had a significantly higher pH, water holding capacity (WHC), moisture content, Myofibrillar fragmentation index (MFI), processing yields, tenderness, and sensorial scores than samples containing cold-boned beef ( $p<0.05$ ). Regardless of the raw materials, the jerky containing soy sauce had a significantly lower pH, WHC, moisture content, salt content, TBA, CIE L\* and b\* values, and significantly higher MFI, mechanical tenderness, and sensorial scores ( $p<0.05$ ). Based on these findings, we concluded that the use of hot-boned meat and soy sauce was the most effective boning method and curing agent during beef jerky processing.

**Key words:** curing, hot-boning, jerky, salt, soy sauce, texture

### Introduction

Carcass boning or production of retail cuts containing bones can be performed in the traditional manner on a chilled carcass for products designated for the retail steak and roast trade and for sausage manufacturing and minced meat. However, an alternative boning technique has also been developed using the pre-rigor hot carcass, from which the tissue is primarily used for meat or sausage manufacture (Ockerman and Basu, 2004). Hot boning is usually performed the day after slaughter when rigor mortis is complete, and has potential advantages relative to cold boning including a higher meat yield, labor saving (20%), less weight loss during chilling (1.5%), less drip loss in vacuum packages (0.1-0.6%), a more uniform product, a darker color, less refrigerator space (50-55%) and refrigeration cost (40-50%), shorter processing time (40-50%), and lower transport costs (Ockerman and Basu, 2004; Pisula and Tyburcy, 1996; Waylan and Kast-

ner, 2004).

Salt is the most commonly used functional ingredient in processed meat product, and is used primarily for flavour but also has secondary functions including inhibiting microbial growth, extending shelf-life and increasing protein hydration. It increases protein hydration by increasing the ionic strength in meat products, and increased protein hydration leads to increased water binding in intact muscle pieces and increased soluble protein concentrations in comminuted meat products (Chinachoti and Schmidt, 1991; Mills, 2004). Chinachoti and Schmidt (1991) reported that the effects of salt on protein hydration had been an important aspect of water binding studies, because the water binding capacity of a protein significantly influenced functionality. Also, most of the protein that is brought into solution with the addition of salt is myosin, and soluble myosin has excellent emulsification and gelling properties. Thus, salt addition is critical for creating a stable structure in finely comminuted products (Mills, 2004). Soy sauce, which is produced in large quantities in Asia and the USA, is made through a long, elaborate fermentation process using various fungi, bacteria, and yeast (Lam and de Lumen, 2003). In Korea, home-made soy sauce is prepared using a traditional

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method, where cooked soybeans are mashed and made into small balls (called *meju*), which are dried in the sun during the day and kept warm at night for several days during the winter, and then the ripened *meju*-brine mixture is separated into supernatant liquid (soy sauce) and sediment residue (soybean paste) (Sasaki and Nunomura, 2003). Soy sauce manufacturing was modernized much earlier than other soy foods, and both fermentation and acid hydrolysis are used to produce different types of soy sauce that are now commonly available around the world (Snyder and Wilson, 2003). In Asia, cured (or marinated) foods are prepared using these ingredients, and are cured in the presence of water within a certain period of time (Lan and Chen, 2002).

To date, only a limited number of studies have examined the effect of using hot-boned meat curing and agents during jerky processing. Therefore, the goal of this study was to evaluate the quality properties of semi-dried beef jerky prepared from hot-boned or cold-boned beef meats with soy sauce or salt solution, and to determine if hot-boning and curing agents can be effectively utilized for jerky processing.

## Materials and Methods

### Raw materials and curing solution preparation

Twelve female feedlot-fed Korean native cow (Hanwoo, 24 mon of age, live weights: 574-681 kg, slaughter weights: 353-435 kg, quality grade: 2-3) were obtained at a local municipal slaughterhouse. After splitting and bleeding, the carcasses were transferred to the cutting room. *Semi-membranosus* muscles were removed immediately, and trimmed of all subcutaneous fat and connective tissue. The part of muscles (the average weight: 237.68 g) were placed in polyethylene bags, and transported to the Konkuk University Meat Science Laboratory. After the meat samples were cut into two parts of equal size, half of the carcasses were hot-boned within 90 min post-mortem and the other half (cold-boned samples) were chilled at 4°C until 48 h. The physicochemical characteristics of raw materials are shown in Table 1. Lean beef were ground through an  $\Phi$  8 mm plate. Commercial soy sauce (Fermented soy sauce, Sempio Foods Co., Korea) was purchased from a local market. Soy sauce showed pH 4.8 and 16% salt concentration. Soy sauce solution and salt (Hanju Corporation, Ulsan, Korea) solution, which were diluted with ice water for adding same salt and water contents, were made at 2% salt concentration and these solutions were added into ground beef. All samples were

composed by 80% raw meat, 20% water, and 2% total salt concentration.

### Preparation of jerky

The ground beef meat was mixed with curing solution by hand for 3 min. The meat was then continuously tumbled in a tumbler (MGH-20, Vackona, Liesen, Germany) at 4°C for 30 min at 25 rpm. Cured meat was stuffed into cellulose casing ( $\Phi$  20 mm), and dried in a convection dry oven (Enex-CO-600, Enex, Yongin, Korea) for 180 min at 55°C, for 180 min at 65°C, and for 60 min at 75°C (Choi *et al.*, 2008).

### pH measurement

The pH of samples was determined with a pH meter (Model 340, Mettler-Toledo GmbH, Schwerzenbach, Switzerland). pH values were measured by blending a 5 g sample with 20 mL distilled water for 60 s in a homogenizer (Ultra-Turrax T25, Janke & Kunkel, Staufen, Germany).

### Water holding capacity (WHC)

The water holding capacity of raw and cured meat was measured by the procedure of Grau and Hamm (1953). Briefly, a 300 mg sample of muscle was placed in a filter press device and compressed for 3 min. WHC was calculated from samples as a ratio of the meat film area to the total area; hence, a larger value suggests a higher WHC.

### Instrumental color measurements

Instrumental color measurements were taken with a color meter (Chroma meter CR-210, Minolta, Japan; illuminate C, calibrated with white standard plate  $L^* = 97.83$ ,  $a^* = -0.43$ ,  $b^* = +1.98$ ) by measuring on the surface of cured meats. For color analysis, the cured meat placed into Petri dish (90×15 mm).

### Moisture contents and water activity

Moisture contents were determined by weight loss after 24 h of drying at 105°C in a drying oven (SW-90D, Sang Woo Scientific Co., Bucheon, South Korea) as recommended by AOAC (1995). Samples for water activity were minced into pieces approximately 1 mm<sup>3</sup> in size, and the water activity of each sample was determined in duplicate with a hygrometer (BT-RS1, Rotronic ag., Bassersdorf, Switzerland).

### Processing yields

Processing yields were determined by calculating the

weight differences of jerky before and after drying as follows:

$$\text{Processing yields (\%)} = \frac{\text{jerky weight after drying}}{\text{cured meat weight before drying}} \times 100$$

#### Salt concentration

A 5 g samples were diluted with 45 mL distilled water and homogenized for 60 s in a homogenizer (Ultra-Turax T25, Janke & Kunkel, Staufen, Germany). The salt concentration of each sample was measured with a salt meter (TM-30D, Takemura Electric Works Ltd., Tokyo, Japan).

#### Thiobarbituric acid (TBA) value

TBA values were determined using the distillation method of Tarladgis *et al.* (1960). Results were expressed as mg of malonaldehyde per kg of sample.

#### Myofibrillar fragmentation index (MFI) measurements

Myofibrils were obtained according to the method of Olson *et al.* (1976) using MFI buffer (20 mM  $K_2HPO_4/KH_2PO_4$ , pH 7, 100 mM KCl, 1 mM EDTA, and 1 mM  $NaN_3$ ). 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 was measured at 540 nm. MFI values were recorded as absorbance units per 0.5 mg/mL myofibril protein concentration multiplied by 200 (Yu *et al.*, 2005).

#### Shear force measurement

Shear force values were determined with a Warner-Bratzler shear attachment on a texture analyzer (TA-XT2i, Stable Micro System Ltd., Surrey, UK). Test speeds were set at 2.0 mm/s. Data were collected and analyzed from the shear force values to obtain the maximum force required to shear through each sample.

#### Rehydration capacity measurements

The rehydration capacity of beef jerky samples was measured according to the method of Yun *et al.* (1988) and Kim *et al.* (2008). Samples were cut to a size of 10 mm. Cut samples and 50 mL distilled water were combined in a 100 mL beaker at 25 and 37°C, and the weight of soaked sample was measured after 5, 10, 15, 20, 30, 45, and 60 min. Rehydration capacity was determined as

follows:

$$\text{Rehydration capacity (\%)} = \frac{(\text{jerky weight after rehydration} - \text{jerky weight before rehydration})}{\text{jerky weight before rehydration}} \times 100$$

#### Sensory evaluations

Each jerky sample was subjected to sensory evaluations. The samples were served to 12 panel members with previous experience. Panelists were presented with randomly coded samples. The color (1 = extremely undesirable, 10 = extremely desirable), flavor (1 = extremely undesirable, 10 = extremely desirable), tenderness (1 = extremely tough, 10 = extremely tender), juiciness (1 = extremely dry, 10 = extremely juicy), and overall acceptability (1 = extremely undesirable, 10 = extremely desirable) of the samples were evaluated using a 10-point horizontal scale. Panelists were required to cleanse their palate between samples with water.

#### Statistical analysis

An analysis of variance were performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (SAS Inst., 1999). The Duncan's multiple range test ( $p < 0.05$ ) was used to determine differences among the treatment means.

## Results and Discussion

#### Properties of raw materials

The temperatures of the cold-boned and hot-boned beef meat during the jerky processing were 4.08 and 36.55°C, respectively (Table 1), and the hot-boned meat had a significantly higher pH and water holding capacity (WHC) than those of cold-boned beef ( $p < 0.05$ ). Keenan *et al.* (2010) reported that the temperature of hot-boned beef

**Table 1. Physicochemical properties of raw materials**

Traits	Cold-boned beef	Hot-boned beef
Temperature at processing (°C)	4.08±0.07 <sup>B</sup>	36.55±0.41 <sup>A</sup>
pH	5.55±0.04 <sup>B</sup>	6.58±0.04 <sup>A</sup>
WHC <sup>1</sup> (%)	46.72±1.21 <sup>B</sup>	50.52±1.63 <sup>A</sup>
CIE L*	39.46±1.92 <sup>A</sup>	27.89±1.85 <sup>B</sup>
CIE a*	31.33±1.79 <sup>A</sup>	13.00±1.24 <sup>B</sup>
CIE b*	19.03±1.62 <sup>A</sup>	3.15±0.53 <sup>B</sup>

All values are mean±SD.

<sup>A,B</sup>Means in the same row with different letters are significantly different ( $p < 0.05$ ).

<sup>1</sup>WHC: Water holding capacity

muscles ranged from 34–35°C, whereas the temperature for cold-boned muscles ranged from 2–4°C. Thomas *et al.* (2008) reported that the temperature of cold-boned and hot-boned pork meat at the time of processing were 4.27 and 36.20°C, respectively, and hot-boned meat (6.80) had a significantly higher pH than that of cold-boned meat (5.60). In addition, Berry *et al.* (1996) found that patties produced from hot processing treatment had a higher ( $p < 0.05$ ) pH in the raw and cooked form than patties obtained from cold processing treatment. Furthermore, Reagan *et al.* (1981) reported that the desirable meat products-making characteristics of pre-rigor meats included high muscle pH, high WHC, and higher protein solubility. A difference in the meat instrumental color was also observed between the raw meat, where the hot-boned beef had significantly lower CIE  $L^*$ ,  $a^*$ , and  $b^*$ -values than cold-boned beefs. These findings were in agreement with a study by the Lee and Kim (1991), who reported that meat color in the *Longissimus dorsi* was significantly darker in the hot boning beef than in the cold boning beef. Also, Waylan and Kastner (2004) found that the color of hot-processed beef cuts packaged in oxygen-permeable over-wrapped retail trays was typically darker than that of cold-processed cuts; however, the color was not deemed unacceptable.

### Properties of cured meats

The effects of the boning method and curing agent on the properties of cured meats are shown in Table 2. The cured meat containing hot-boned beef had a significantly higher pH and WHC than cold-boned regardless of the curing agent ( $p < 0.05$ ), and for both hot- and cold-boned meat, samples prepared with soy sauce had a significantly lower pH and WHC than the samples prepared with salt ( $p < 0.05$ ). This may be due to the fact that the hot-boned meat had a higher pH and WHC (Table 1) and the soy sauce in the curing solution had a lower pH. Mongkolwai

**Table 2. pH, water holding capacity, and color of cured meats**

Treatments	Cold-boned beef		Hot-boned beef	
	Salt	Soy sauce	Salt	Soy sauce
pH	5.59±0.03 <sup>C</sup>	5.44±0.04 <sup>D</sup>	6.24±0.07 <sup>A</sup>	6.17±0.07 <sup>B</sup>
WHC <sup>1</sup> (%)	48.83±2.70 <sup>C</sup>	40.86±2.89 <sup>D</sup>	93.31±1.17 <sup>A</sup>	88.93±2.03 <sup>B</sup>
CIE $L^*$	37.19±0.94 <sup>A</sup>	33.24±0.80 <sup>B</sup>	36.37±1.52 <sup>A</sup>	28.05±3.17 <sup>C</sup>
CIE $a^*$	28.56±2.64 <sup>A</sup>	22.90±1.25 <sup>BC</sup>	24.38±1.43 <sup>B</sup>	21.45±1.78 <sup>C</sup>
CIE $b^*$	15.44±1.41 <sup>A</sup>	14.99±1.39 <sup>A</sup>	10.26±0.88 <sup>C</sup>	13.05±1.30 <sup>B</sup>

All values are mean±SD.

<sup>A-D</sup>Means in the same row with different letters are significantly different ( $p < 0.05$ ).

<sup>1</sup>WHC: Water holding capacity

*et al.* (1997) found that the pH of Thailand commercial soy sauce and black soy sauce was 4.5–5.3 and 4.5–5.5, respectively, and Lee *et al.* (1997) reported that the pH of Korean traditional soy sauce (*kanjang*) and commercial soy sauce ranged from 4.92–5.12, and 4.51–4.66, respectively.

Also, the boning method and curing agent affected the color of the cured meats, where the cured samples with salt were significantly lighter and redder in color than the samples prepared with soy sauce ( $p < 0.05$ ). In addition, for the same curing agent, the cured meat with hot-boned beef had significantly lower CIE  $L^*$ ,  $a^*$ , and  $b^*$ -values than the samples with cold-boned meat ( $p < 0.05$ ). Claus and Sørheim (2006) reported that patties made from pre-rigor ground beef were slightly less red. In addition, Sørheim *et al.* (2006) found that the patties subjected to pre-rigor treatments had a more light yellowish external color than patties subjected to post-rigor treatment.

### pH, moisture contents, and water activity of jerky

The pH, moisture contents, and water activity of the semi-dried beef jerky prepared with different boning methods and curing agents are provided in Table 3. The beef jerky prepared with soy sauce had significantly lower pH, moisture contents, and water activity than the

**Table 3. Physicochemical properties of semi-dried beef jerky**

Treatments	Cold-boned beef		Hot-boned beef	
	Salt	Soy sauce	Salt	Soy sauce
pH	5.90±0.02 <sup>C</sup>	5.76±0.02 <sup>D</sup>	6.32±0.07 <sup>A</sup>	6.24±0.07 <sup>B</sup>
Moisture contents (%)	31.01±0.61 <sup>C</sup>	29.55±0.55 <sup>D</sup>	41.38±1.47 <sup>A</sup>	39.80±1.54 <sup>B</sup>
Water activity	0.85±0.02 <sup>B</sup>	0.83±0.01 <sup>C</sup>	0.89±0.01 <sup>A</sup>	0.89±0.01 <sup>A</sup>
Salt concentration (%)	4.95±0.13 <sup>A</sup>	4.74±0.15 <sup>B</sup>	4.74±0.14 <sup>B</sup>	4.64±0.39 <sup>B</sup>
TBA (mg MDA/kg)	0.25±0.03 <sup>A</sup>	0.15±0.01 <sup>B</sup>	0.24±0.03 <sup>A</sup>	0.12±0.01 <sup>C</sup>
MFI <sup>1</sup>	5.20±0.40 <sup>C</sup>	5.33±0.12 <sup>C</sup>	6.53±0.31 <sup>B</sup>	7.40±0.28 <sup>A</sup>

All values are mean±SD.

<sup>A-C</sup>Means in the same row with different letters are significantly different ( $p < 0.05$ ).

<sup>1</sup>MFI: Myofibrillar fragmentation index

samples prepared with salt ( $p < 0.05$ ), except for the water activity within hot-boning treatments. This was due to the fact that the soy sauce had a lower pH, and the cured meats prepared with soy sauce had a lower WHC. In addition, the jerky samples prepared with hot-boned beef had significantly higher pH, moisture contents and water activity than samples prepared with cold-boned beef because hot-boned raw and cured meat had a higher pH and WHC ( $p < 0.05$ ). These findings are in agreement with the study by Huff-Lonergan and Lonergan (2005), who demonstrated that as rigor progressed, the space for water to be held within the myofibrils was reduced and fluid could be forced into the extramyofibrillar spaces where it was more easily lost as drip, and therefore the accelerated decrease in the pH of meat (or meat products) were related to the development of low WHC and unacceptably high purge loss. Pisula and Tyburcy (1996) noted that the functional properties of hot-boned meat were superior to cold-boned meat due to the higher pH and ATP level, dissociation of actomyosin and better solubility of myofibrillar proteins. Honikel (2004) also reported that muscles in the pre-rigor state could contract if the ATP levels were sufficient for contraction and the temperature was lowered too rapidly or too slowly, and this contraction enhanced drip loss. Rees *et al.* (2002) also reported that the higher muscle contraction of cold shortened muscle resulted in a higher drip loss and moisture loss. The moisture contents and water activity of the semi-dried beef jerky prepared in this study ranged from 29-42% and 0.83-0.89, respectively. Similar results were obtained by Choi *et al.* (2008) who found that semi-dried jerky with various pork/beef levels and casings had moisture contents ranging from 34-37% and water activities ranging from 0.82-0.88, and Leistner (1987) examined Chinese dried meats that were dried for several hours at 50-60°C, until they reached approximately 50% of their original weight or 35±5% moisture contents, and these meats were prepared preferably from hot-boned meat, which required little energy and only simple equipment for processing.

#### **Salt concentration and TBA of jerky**

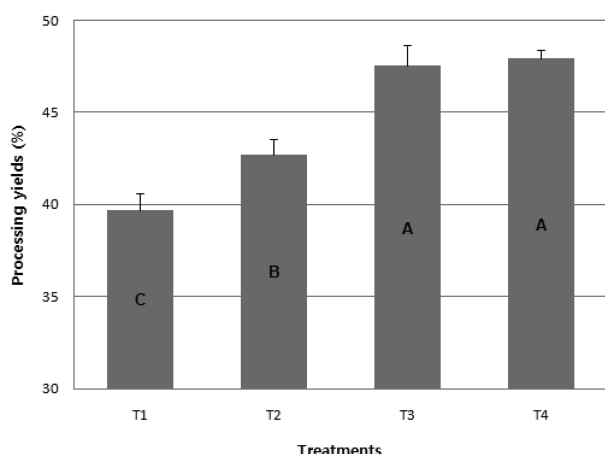
Lipid oxidation is a major cause for the deterioration in flavor, odor, taste, color, texture, and appearance, leading to spoilage in meat and meat products, and these quality changes were shown to be accelerated by the addition of salt to foods (Aalhus and Dugan, 2004; O'Neill *et al.*, 1999). As shown Table 3, the semi-dried jerky prepared with cold-boned meat and salt solution had higher salt

concentration than other treatments, and no differences ( $p > 0.05$ ) were observed between the hot-boned meat treatments. Also, when the curing solution was used, distinct changes were observed in the TBA values of the samples, and the jerky samples containing soy solution had significantly lower TBA values than the samples containing the salt solution ( $p < 0.05$ ). Lee *et al.* (2006) found that dark soy sauce had a rapid antioxidant effect against lipid peroxidation, and this effect was accompanied by vasodilatory haemodynamic changes in vascular function consistent with antioxidant effects on the endothelium or vascular smooth muscle. Moon *et al.* (2002) and Rufian-Henares and Morales (2007) demonstrated that melanoidin, which is formed at the last stage of the Maillard reaction, is the major factor dictating the antioxidant activity of soy sauce. In the soy sauce treatments, the TBA values of cold-boned beef jerky were higher than hot-boned treatment was used. An increase of salt concentration in the semi-dried beef jerky led to an increase of the TBA values in the final products. Except for the slight difference in salt concentrations for the hot-boning treatments, these results were in agreement with the study of Ockerman (1983) indicating that the increased TBA values in meat products were responsible for the increased salt concentration. Also, Bernthal *et al.* (1989) found that the use of salted pre-rigor beef meat in oxidation susceptible restructured products could delay or inhibit rancidity development, and Moore *et al.* (1992) reported that country cured hams prepared from hot processed treatments tended to have a slightly lower in salt contents, which was probably due to their higher WHC.

#### **Processing yields, shear force, and MFI of jerky**

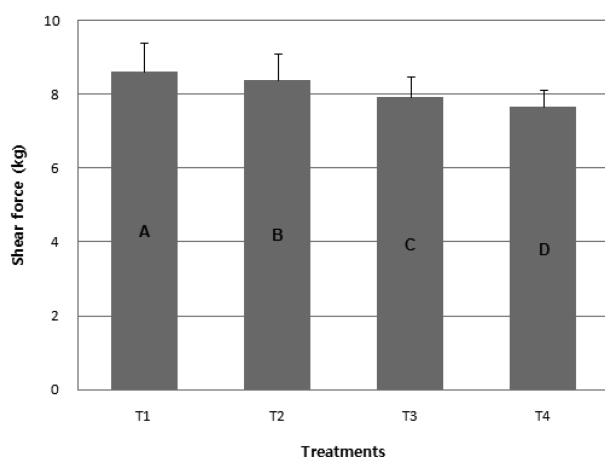
The effects of boning methods and curing agent on the processing yields of semi-dried beef jerky are shown in Fig. 1. The jerky prepared with hot-boned beef had significantly higher yields than those prepared with cold-boned ( $p < 0.05$ ), regardless of curing agent, which may be due to the fact that the hot-boned beef meat and jerky had a significantly higher WHC and moisture contents (Table 1). Ockerman and Wu (1990) demonstrated that pork sausages prepared with chilled pork samples had a higher percent of free water, moisture loss, and cooking loss than hot-boned samples and this may be due to the fact that hot-boned meat had a higher emulsifying capacity and WHC than chilled meat, and Rees *et al.* (2002) found that the higher muscle contraction of cold shortened muscle resulted in a higher drip loss and moisture loss.

In this study, the tenderness of semi-dried jerky was



**Fig. 1. Comparison on processing yields of semi-dried beef jerky prepared with hot-boning process and soy sauce as a curing material.** T1, Jerky prepared with cold-boned beef and salt solution; T2, Jerky prepared with cold-boned beef and soy sauce solution; T3, Jerky prepared with hot-boned beef and salt solution; T4, Jerky prepared with hot-boned beef and soy sauce solution. <sup>A-C</sup>Means with different superscripts are significantly different ( $p < 0.05$ ).

assessed by comparing the shear force (Fig. 2) and myofibrillar fragmentation index (MFI) (Table 3). The beef jerky prepared with hot-boned meat had a significantly lower shear force and higher MFI than cold-boned ( $p < 0.05$ ), regardless of curing agent, and for both hot- and cold-boned beef, samples containing the soy sauce solution had a significantly lower shear force and higher MFI than samples prepared with the salt solution ( $p < 0.05$ ).



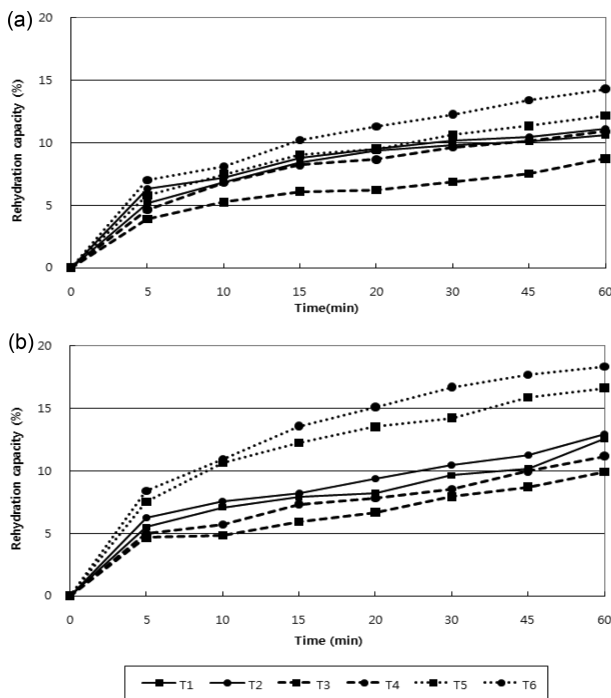
**Fig. 2. Comparison on shear force of semi-dried beef jerky prepared with hot-boning process and soy sauce as a curing material.** T1, Jerky prepared with cold-boned beef and salt solution; T2, Jerky prepared with cold-boned beef and soy sauce solution; T3, Jerky prepared with hot-boned beef and salt solution; T4, Jerky prepared with hot-boned beef and soy sauce solution. <sup>A-D</sup>Means with different superscripts are significantly different ( $p < 0.05$ ).

Especially, the products manufactured with hot-boned beef and soy sauce in the curing solution had a significantly lower shear force and higher MFI than the other treatments ( $p < 0.05$ ). Thus, the hot-boning process and soy sauce enhanced the textural enhancement of beef jerky during manufacturing. Dransfield (1992) suggested that the calpain I is activated and causes proteolysis and tenderization, when the pH of the muscle falls to about 6.1. Berry *et al.* (1999) found that hot processing of beef muscle for patties resulted in greater softness, faster sample preparation during chewing and a greater number of chewed pieces than cold processed patties. In addition, Moore *et al.* (1992) showed that the hot processed hams were tenderer than the cold processed hams, Thomas *et al.* (2008) reported that sausages containing hot-boned pork and fat had a significantly lower hardness ( $p < 0.05$ ), and the increased protein solubility that occurred in hot-boned pork could have resulted in the decrease in the hardness of sausages.

Rees *et al.* (2002) reported an increase in MFI with a reduction in Warner-Bratzler shear force of muscles following accelerated boning, and Tsuji *et al.* (1987) found that the hardness of beef meat decreased with the addition of the raw soy sauce, confirming the tenderizing ability of soy sauce, and the proteinases present in raw soy sauce, rapidly degraded myosin, which contributed to the tenderizing effect of soy sauce could be used to further tenderize meat and meat products.

### Rehydration capacity of jerky

Rehydration is the process of moistening dry material, and this is mostly done by adding abundant amounts of water. In most cases dried food is soaked in water before cooking or consumption; thus rehydration is an important quality criterion of meat (Rahman, 2008). Fig. 3 shows the effects of the boning methods and curing agent on the rehydration capacity of semi-dried beef jerky. The jerky prepared with hot-boned beef had a lower rehydration capacity than cold-boned samples, regardless of the temperature condition, which may be due to the fact that hot-boned meat had a higher water contents. In order to adjust the water contents, the hot-boned samples were dried for 180 min at 55°C, for 180 min at 65°C, and for 240 min at 75°C, and the jerky prepared with hot-boned beef had a great rehydration capacity than jerky prepared with cold-boned meat. Therefore, within the same water contents, hot-boning increased the absorption of water and resulted in the improvement of sensorial texture. Farouk and Swan (1999) found that the rehydration of cold-boned beef soft



**Fig. 3. Comparison on rehydration capacity of semi-dried beef jerky prepared with hot-boning process and soy sauce as a curing material at different temperatures.** (a) Measured at 25°C, (b) Measured at 37°C. T1, Jerky prepared with cold-boned beef and salt solution; T2, Jerky prepared with cold-boned beef and soy sauce solution; T3, T5, Jerky prepared with hot-boned beef and salt solution; T4, T6, Jerky prepared with hot-boned beef and soy sauce solution; T1-T4, Dried for 180 min at 55°C, for 180 min at 65°C, and for 60 min at 75°C; T5, T6, Dried for 180 min at 55°C, for 180 min at 65°C, and for 240 min at 75°C.

jerky was higher than hot-boned meat and the meat slices from cold-boned beef lost more water during dry process; thus jerky prepared with cold-boned meat could absorb more of the infusion solution which resulted in a higher rehydration weight.

In addition, distinct changes in the rehydration capacity of the semi-dried beef jerky were observed at different water temperature. Samples soaked in 37°C had a higher

rehydration capacity than those soaked in 25°C, which is in agreement with the results of Krokida and Marinos-Kouris (2003), who reported that the water temperature influenced the rehydration rates and the equilibrium moisture content in a positive way, and the rehydration ability appeared to show a hysteresis during rehydration due to cellular and structural disruption that took place during drying.

### Sensorial properties of jerky

The sensorial properties of semi-dried beef jerky prepared with various boning methods and curing agents are given in Table 4. Hot boning had a significant influence on all the sensorial traits of the jerky samples, and within hot-boning treatments, the flavor and overall acceptability for the jerky prepared with soy sauce solutions had significantly higher scores than did the samples prepared with the salt solutions. Also, for the cold boning jerky, soy sauce had a significantly positive effect on the sensorial color and overall acceptability of semi-dried beef jerky ( $p < 0.05$ ). Pietrasik and Shand (2003) reported that the sensory traits, such as flavor, tenderness, and texture were negatively affected by moisture loss in meat and meat products during and after thermal processes. The sensorial properties of the jerky improved with hot-boning and soy sauce and this may be due to the increase in moisture contents and WHC in hot-boned meat (Huff-Lonergan and Lonergan, 2005; Rees *et al.*, 2002) and the tenderizing ability of soy sauce (Tsuji *et al.*, 1987). Thomas *et al.* (2008) reported that hot-processed sausages had a significantly higher overall acceptability on the day of processing compared to the cold-processed samples.

In conclusion, the use of hot boned beef meat was positively correlated with the pH, WHC, moisture contents, MFI, processing yields, mechanical tenderness and sensorial properties of cured meat and jerky samples. In addition, soy sauce improved the textural and sensorial properties of beef jerky, and the decreased TBA values of

**Table 4. Sensorial properties of semi-dried beef jerky**

Treatments	Cold-boned beef		Hot-boned beef	
	Salt	Soy sauce	Salt	Soy sauce
Color	7.40±0.50 <sup>C</sup>	7.68±0.48 <sup>B</sup>	8.12±0.33 <sup>A</sup>	8.28±0.46 <sup>A</sup>
Flavor	7.28±0.46 <sup>C</sup>	7.44±0.51 <sup>C</sup>	8.12±0.73 <sup>B</sup>	8.56±0.51 <sup>A</sup>
Tenderness	7.76±0.66 <sup>B</sup>	7.88±0.60 <sup>B</sup>	8.32±0.69 <sup>A</sup>	8.56±0.71 <sup>A</sup>
Juiciness	7.24±0.66 <sup>B</sup>	7.44±0.65 <sup>B</sup>	8.32±0.69 <sup>A</sup>	8.56±0.65 <sup>A</sup>
Overall acceptability	7.36±0.64 <sup>D</sup>	7.68±0.56 <sup>C</sup>	8.24±0.44 <sup>B</sup>	8.56±0.51 <sup>A</sup>

All values are mean±SD.

<sup>A-D</sup>Means in the same row with different letters are significantly different ( $p < 0.05$ ).

jerky prepared with the soy sauce solution were responsible for the decreased salt concentration. Therefore, the combination of hot-boning and soy sauce had a positive effect on semi-dried beef jerky in regards to the textural and sensory properties.

### Acknowledgement

This paper was supported by Konkuk University in 2010.

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(Received 2011.6.10/Revised 2011.6.28/Accepted 2011.6.30)