Korean J. Food Sci. Ani. Resour.
Vol. 30, No. 5, pp. 722~729(2010)

ARTICLE

Evaluation of Microbiological, Physicochemical, and Sensory Properties of *Galbi-jjim* Prepared by *Sous-vide* and Cookchill Method at Different Temperatures

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Abstract

The aim of this study was to evaluate the physico-chemical, sensory, and microbiological properties of ready-to-eat Korean traditional seasoned beef ribs ("*galbi-jjim*") prepared by *sous-vide*/cookchill technology during storage at three different temperatures (4, 10, and 20°C). Beef short ribs marinated in soy sauce for 24 h at 3°C were packed with vegetables under vacuum. Vacuum-packed beef ribs mixed with vegetables were heated at 90°C for 90 min in a water bath, and then immediately chilled below 3°C within 120 min in an ice slurry. Physicochemical (pH, water activity, TBARS, L*a*b* color, and texture profile), sensory (appearance, odor, flavor, texture, and acceptance) and microbiological (Coliform, *Escherichia coli*, food-borne pathogenic bacteria) properties of the samples were determined during storage at different temperatures. Results showed that pH, a_w, and sensory evaluation of products were not affected in any consistent way as a function of either storage duration or temperature. Coliform, *E. coli* and food-borne pathogens were not detected during storage at any temperature. However, TBARS significantly increased during storage period ($p<0.05$). Based on TBARS values, SV/CC "*galbi-jjim*" can be stored for 15 d, 12 d and 1 d at 4, 10 and 20°C, respectively.

Key words: *sous-vide*/cook-chill, sensory quality, microbiological safety, temperature abuse simulation

Introduction

Many Korean traditional dishes require time-consuming and intensive labor for preparation and cooking (Paik *et al*., 2006), whereas they have limited storage stability at normal refrigeration temperature. Consumers demand foods that are convenient, easy to prepare, high quality and preservative-free (Galimpin-Johan *et al*., 2007; Koo *et al*., 2008; Paik *et al*., 2006). As two-income households, working mothers, singles, and seniors have increased, the market for convenient food has grown remarkably. Consequently, the production of intermediate food or ready-to-eat meals in cold chain have became more popular compared to traditional home-cooked meal (Johnson and Resurreccion, 2009).

Sous-vide/cook-chill (SV/CC) technology is a cooking procedure originated in France in the mid-1970s. SV/CC system is defined as raw or par-cooked foods are vacuum-sealed in a barrier pouch or container, cooked slowly in controlled mild heating conditions, rapidly chilled, stored at refrigeration temperatures and reheated for consumption (Creed, 1998; Ghazala *et al*., 1995; Schellekens, 1996; SVAC, 1991). SV/CC technology is applied to catering industries, food service sectors and ready meal-type food productions (Creed, 1998; Vaudagna *et al*., 2002).

Previous studies (González-Fandos *et al*, 2004; Schellekens, 1996) have shown that SV/CC technology is possible to extend the shelf-life from 6 to 42 d. SV/CC applied foods are generally processed using a mild heat treatment and requires a long heating time at low temperature to retain tenderness, juiciness and microbiological safety (bacterial pathogens).

As the poiuts of the quality, SV/CC is a highly advanced technology because of convenience, better sensory quality and retention of water-soluble nutrition than conventional cooked food (Schellekens, 1996; Vaudagna *et al*., 2008). Nevertheless, anaerobic and temperature abuse conditions of SV/CC cooked foods can cause potential

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microbiological hazards during the product circulation and at the consumer level (Schellekens, 1996; Tansey *et al*., 2005). In our previous report, the optimal textural and sensory conditions of SV/CC processing were investigated to develop the ready-to-eat (RTE) Korean tradition "*galbi-jjim*" (Kim, Park and Shin, 2009). As a result, the control temperatures of SV/CC processed "*galbi-jjim*" satisfied the guidelines of ACMSF (Advisory Committee on the Microbiological Safety of Food, U.K., 2004), ECFF (European Chilled Food Federation, U.K., 1996), Food code (FDA, U.S.A., 2005) and DHSS (Department of Health and Social Security, U.K., 2003).

Therefore, the objective of this study was to evaluate the physico–chemical, sensory quality and microbiological safety of the ready-to-eat (RTE) type "*galbi-jjim*" product at normal refrigeration temperature (4°C) and temperature-abused conditions (10°C and 20 °C) (FDA, USA, 2005; ACMSF, UK, 2004) for industrial application.

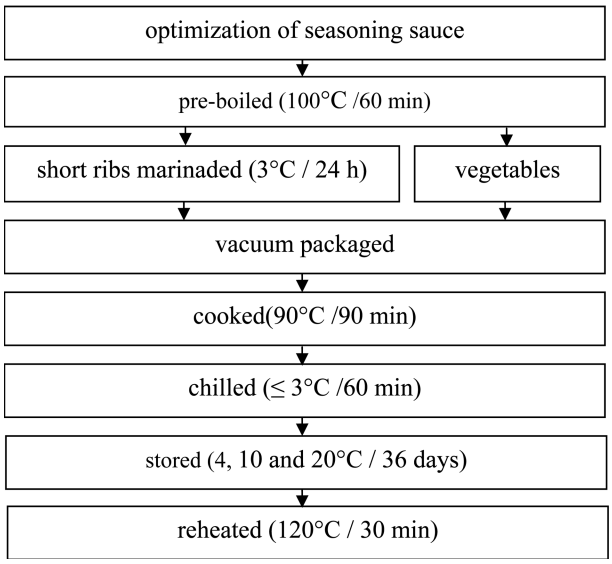

Fig. 1. The *sous-vide*/cookchill process of Korean traditional *galbi-jjim*.

Materials and Methods

Preparation of sous-vide "*galbi-jjim*"

Beef short ribs for *sous-vide*/cookchill were purchased from a local market (Seoul, Korea) and cut into 4.9×3.1×3 cm pieces. The SV/CC "*galbi-jjim*" was processed as shown in Fig. 1. Briefly, the beef short ribs were submerged in cold water for 2 h to remove blood and cooked in boiling water for 60 min. The pre-cooked beef short ribs were marinated in seasoning sauce for 24 h at 3°C before vacuum packing. Beef short ribs and vegetables (carrots, gingko nuts, taro, and shiitake mushrooms) were vacuum-packed in nylon/ PE/ LLDPE pouch (Samhosa Co., Ltd., Seoul, Korea) using a vacuum sealing machine (SH-100/SMV-206T, Samhosa Co., Ltd., Seoul, Korea) under 760 mm Hg pressure. The products were cooked at 90°C for 90 min in a water-bath with a meat core temperature of 85°C/60 min and immediately chilled in an ice slurry jacket until the internal temperature reached ≤3°C within 1 h.

The pasteurization and chilling method was followed to UK ACMSF (2004), UK ECFF (1996), FDA (2005) and UK DHSS (2003) guidelines. Chilled products were stored at 4°C (FRB-4230N, Daewoo, Seoul, Korea), 10°C and 20°C (Temperature & Timer controller; HB-103S, Han Baek Scientific Co., Seoul, Korea) for 36 d for sensory evaluation, physicochemical and microbiological analysis.

Physicochemical analysis

Water activity, pH, 2-thiobarbituric acid reactive substances (TBARS), CIE L^* a^* b^* color and texture profile were performed during storage (3-d intervals) at 4, 10 and 20°C. The products stored at 4°C and 10°C were analyzed after 1, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33 and 36 d, and those at 20°C were analyzed after 1, 3, 6, 9, 12 and 15 d.

The water activity (a_w) was determined by the Conway Unit Method (Sibata Scientific Technology Ltd., Tokyo, Japan). Three gram of potassium dichromate (regent A) and potassium mitrate (reagent B) was pur into the outside cell, separately. A sample (1 g) was placed in an aluminum weighing case and the lid, and closed to stand in a thermostat at 25 (±2)°C for 2 (±0.5) hours. The water activity (a_w) value was calculated according to the following equations:

$$a_w = B \times X - A \times Y/X - Y$$

A: a_w value of regent (wet) A
B: a_w value of regent (wet) B
X: increase or decrease of weight with A
Y: increase or decrease of weight with A

The pH measurements (Vaudagna *et al*., 2008) were performed with a pH meter (Model M530 Pinnacle, Corning, USA). A sample (5 g) was mixed with distilled water (25 mL) for 30 sec using a blender (HMF-505, Hanil Electric Inc., Bucheon, Korea) and filtered through Whatman filter paper No. 2 (Advantec No. 2/ TY2, Toyo, Japan).

TBARS was determined by a modification of the previous methods (Choi *et al*., 2002; Witte *et al*., 1970). The

refrigerated sample (5 g) was mixed with 12.5 mL of 20% trichloroacetic acid in 2 M phosphoric acid and homogenized with 10 mL of distilled water for about 40 seconds in a blender (HMF-505, Hanil Electric Inc., Bucheon, Korea). The distilled water was added until the volume reached to 25 mL, centrifuged at 1500 rpm for 15 min using a centrifuge (VS-21SMTi, High Speed Refrigerated Centrifuge, Vision, Seoul, Korea), and filtered (No. 1, *Whatman* International Ltd., Maidstone, UK). The filtered solution (2 mL) was mixed with 2 mL of fresh 0.005 M 2-thiobarbituric acid solution (TBA) and left for 15 h at room temperature for reaction. The absorbance was measured at 530 nm with a spectrophotometer (Ultrospec® 2100 pro, Biochrom, UK), and the TBARS value was calculated according to the following equations:

TBARS (mg malonaldehyde/kg sample)
= Absorbance at 530 nm × 5.2

The meat color was measured both on the surface and in a cross section of cut meat into half with a color meter (Minolta CR-400, Minolta Co., Ltd., Japan). Color was recorded with the Hunter L^* value (darkness to lightness), a^* value (greenness to redness) and b^* value (blueness to yellowness) scale and the instrument was calibrated using a white standard tile prior to use. The calibration value was 96.03 at L^* value, 0.16 at a^* value and 2.07 at b^* value. Triplicate readings per product were performed.

Hardness of the beef short rib was tested using a TA.XT 2i/25 texture analyzer (Stable Micro system, London, UK) during the storage period at room temperature. Beef short ribs were cut into 1.5×1.5×1.5 cm and measurements were conducted using an aluminum cylinder probe with 2 cm in diameter. The measuring condition was followed as below pre-test speed: 3.0 mm/s, test speed: 1.0 mm/s, post-test speed: 1.0 mm/s, strain: 80%, time: 2.0 s and force: 5.0 g. The hardness of beef short rib was expressed as kilogram (kg). The entire experiments are conducted in triplicate.

Sensory analysis

The sensory evaluation of the samples stored for 0 (freshly cooked "*galbi-jjim*"), 7, 14, and 21 d was conducted. The period of the sensory test was set by preliminary tests in our laboratory. The intensity sensory evaluation was carried out by 35 panelists from Hanyang University students (Seoul, Korea). Prior to serving to the panelists, each product was reheated reaching to 75°C or above (DHSS, 2003) of internal temperature within 30 min in the combination oven (CS-0405, Daeyung Bakery Machinery Ind., Co., Ltd., Seoul, Korea). The sample was placed on white lidded pottery with random three-digit numbers after removal of bone from sample and cut into 1.5×1.5×1.5 cm cubes. The panelists evaluated the reheated *Galbi-jjim* using a 15 point structured scale and the scales used for the sensory evaluation were the following: meat color (1 = very light to 15 = very dark), ingredient color (1 = extremely invisible to 15 = extremely visible), oxidized odor (extremely weak to 15 = extremely strong), off-flavor, off-taste, meat juiciness, saliness (1 = extremely weak to 15 = extremely strong) and overall acceptance (1 = dislike extremely to 15 = like extremely).

Microbiological analysis

To determine the microbial quality of stored products, 25 g of sample were aseptically weighed and homogenized in a stomacher (BagMixer®400, Interscience, France) for 2 min with 225 mL of 0.1% peptone water (Difco, Detroit, MI, USA). Decimal serial dilutions in 0.1% peptone water were used for quantification. Cell counts of *Escherichia coli* and coliform were determined on Petrifilm™ *E. coli*/Coliform Count Plate (PEC) (3M, St. Paul, USA). All the samples were analyzed in triplicate.

Other pathogenic bacteria (*Shigella* spp., *E. coli* O157:H7, *Staphylococcus aureus*, *Bacillus cereus*, *Vibrio parahaemolyticus*, *Listeria monocytogenes*, *Yersinia enterocolitica*, *Salmonella* spp.) were detected using PCR assay (Powerchek™ Multiplex-Pathogen Detection kit, Kogene, Seoul, Korea). For the PCR of the enriched sample, 1 mL of enrichment culture was collected after 24 h of incubation. The subsample was centrifuged at 12,000 rpm for 5 min by using microcentrifuge (Micro 17R, Hanil Science Industrial, Korea). The supernatant was carefully removed, and the precipitants were washed twice, and then re-suspended in sterile distilled water. After the suspension was heated at 95°C for 5 min and centrifuged at 10,000 rpm for 10 min, the supernatant was frozen at -20°C. One μL of positive control 1 (*E. coli* O157:H7, *Bacillus cereus*, *Listeria monocytogenes*, *Salmonella* spp.) or control 2 (*Shigella* spp., *Staphylococcus aureus*, *Vibrio parahaemolyticus*, *Yersinia enterocolitica*) DNA template was mixed with 9 μL of sterile distilled water and 10 μL of sterile distilled water was used as a negative control instead of a DNA template. Positive control, negative control and sample DNA template were added to 15 μL of primer master mix and amplificated by PCR (MyCycler™ Personal thermal cycler, Bio-Rad, CA, USA). Amplification conditions were: 5 min at 94°C, 40 cycles

of 30 s at 94°C, 30 s at 60°C and 30 s at 72°C and a final extension of 5 min at 94°C. PCR products were electrophoresed through 2% agarose (SeaKem® LE agarose, Lonza, USA) gel in a TBE buffer (AccuGENE, Lonza, USA).

Statistical analysis

One-Way Analysis of variance data was done using SPSS for Windows 13.0 (SPSS Institute, Chicago, IL, USA) with a factor for storage days. The intensity sensory anaysis was determined Multivariate Analysis of Variance (MANOVA). Means±SD was calculated by Duncan's Multiple Range Test at $p<0.05$.

Results and Discussion

pH and water activity (a_w)

Water activity was not changed as the storage time and temperature increased (Fig. 2).

Fig. 3 shows the pH of products measured during storage. The pH values of samples stored at any temperatures were not significantly ($p<0.05$) different time increased. This result was similar to other reports for SV/CC cooked meat-based products (Galimpin-Johan *et al*., 2007; Jang and Lee, 2005).

TBARS

TBARS values of *galbi-jjims* were measured at the interval of 3 d during storage at three different temperatures are shown in Fig. 4. In several studies, TBARS value of meat increased during storage (Witte *et al*., 1970) and lipid oxidation in cooked meats stored at an improper temperature during storage increased (Igene and Pearson, 1979). Fanco (2002) has reported that TBARS value is usually below 0.46 mg MDA/kg in raw meat and Turner (1954) has shown that the lipid oxidation value of decayed food was 1.2 mg MDA/kg. Also, several researchers (Chang and Chen, 1998; Moon *et al*., 2006) have reported that TBARS value of Korean seasoned meat was high due to some ingredients derived from Korean traditional ingredients such as soy sauce, garlic and ginger. In this study, the TBARS values of *Galbi-jjim* stored at 4°C significantly increased ($p<0.00001$). The initial TBARS value was 0.62 mg MDA/kg and then was over 1 mg MDA/kg after 15 d. After 36 d of storage, the TBARS value of *Galbi-jjim* reached 4.13 mg MDA/kg. TBARS

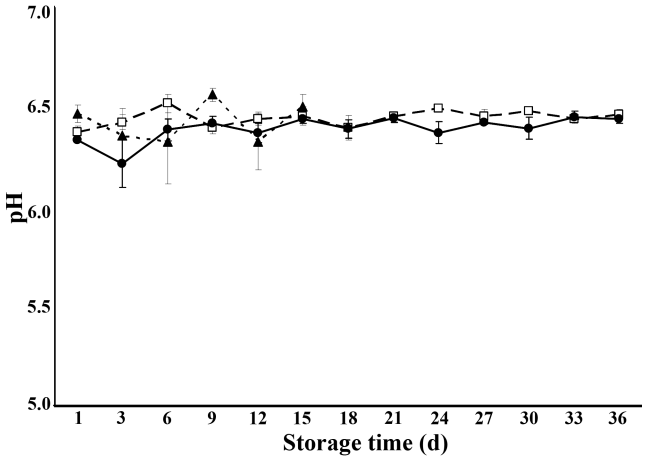

Fig. 3. Change of pH values of beef short rib in *Galbi-jjim* by *sous-vide*/cookchill system during storage at 4°C (●), 10°C (□) and 20°C (▲).

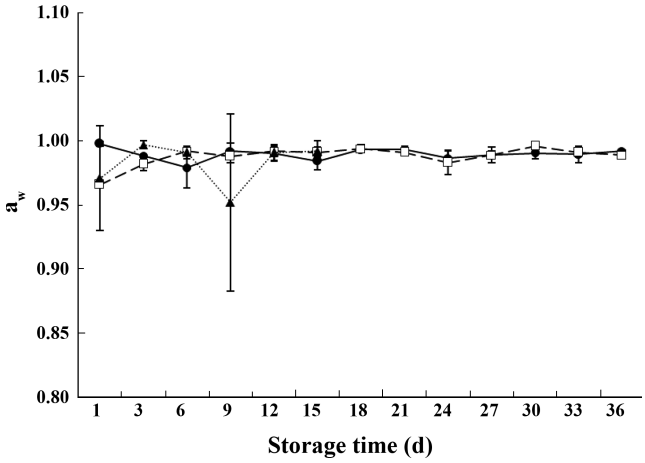

Fig. 2. Change of a_w values in *Galbi-jjim* by *sous-vide*/cookchill system during storage at 4°C (●), 10°C (□) and 20°C (▲).

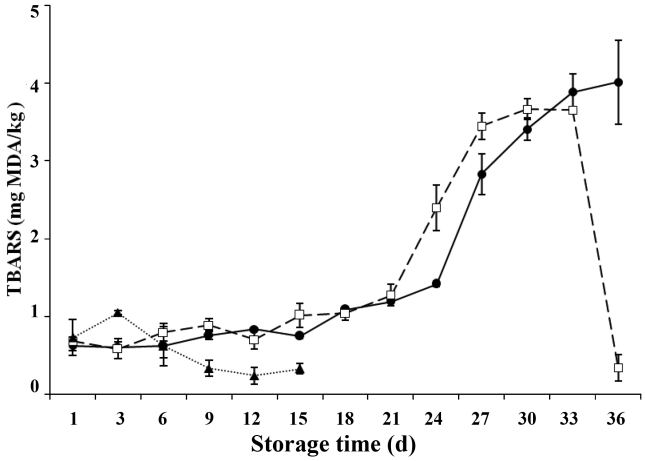

Fig. 4. Change of thiobarbituric acid reactive substance (TBARS) values in *Galbi-jjim* by *sous-vide*/cookchill system during storage at 4°C (●), 10°C (□) and 20°C (▲).

values of *galbi-jjim* stored at 10°C significantly changed over time (p<0.00001). The values increased until 30 d, but rapidly decreased from 3.65 mg MDA/kg to 0.33 mg MDA/kg after 33 d. This result has been in good agreement with Gokalp *et al*. (1983) and Laleye *et al*. (1984), which TBARS values increased due to the formation of malondialdehydrate (MDA) at initial storage, but decreased by combining with amino acid or carbonyl compounds in the meat product after a certain period. When *galbi-jjims* were improperly abused at 20°C, TBARS value reached to 1.06 mg MDA/kg after 3 d, suggesting that malondialdehydrate more rapidly reacted at 20°C than at 4°C and 10°C. Thus, this result shown that TBARS value mainly depends on both storage temperature and time.

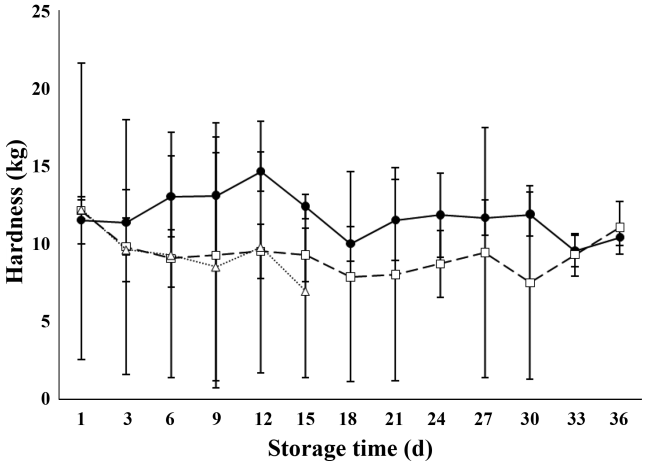

Fig. 5. Change in hardness of *galbi-jjim* by *sous-vide*/cook-chill system during storage at 4°C (●), 10°C (□) and 20°C (▲).

Hardness

The hardness of *galbi-jjim* stored at different temperatures was measured with time course. Statisyically, the storage time did not influence on the change in hardness of *galbi-jjim* samples at any temperatures (p<0.05). Although, the measurements in hardness of *galbi-jjim* samples stored at different temperatures were repeated more than 10 times, the precisive and homogeneous data among the samples were not obtained as shown in Fig. 5. Therefore, we confered that meat used for *galbi-jjim* preparation caused to produce uneven and statisticall insignificant data.

Color

The surface colors of the meat samples were shown in Table 1(A). L^*(lightness) and a^* (redness) value of beef short rib slowly increased with storage days at 4°C. At 10°C, the L^* values were not changed for 18 d, but significantly increased from 22 d (27.26) to 32 d (38.08) (p<0.05). And, L^* value of *galbi-jjims* stored at 20°C was not significantly changed (p>0.05) but a^* values markedly (p<0.05) increased during storage period. However, Fu *et al*. (1992) reported that L^* and a^* values were decreased by producing peptides and amino acids because of the

Table 1(A). Change in surface colors of *Galbi-jjim* by *sous-vide*/cookchill system during storage

Surface color	Storage d										
	1 d	4 d	8 d	11 d	15 d	18 d	22 d	25 d	29 d	32 d	36 d
L* 4°C	28.37±2.66^{a}	30.78±0.76^{a}	34.18±5.29^{a}	31.71±4.55^{a}	34.03±1.64^{a}	31.76±3.69^{a}	32.27±1.25^{a}	34.86±3.31^{a}	30.64±5.40^{a}	29.38±2.98^{a}	34.33±1.14^{a}
10°C	32.13±2.92^{b}	31.90±0.62^{b}	31.93±3.36^{b}	29.78±3.65^{b}	31.65±3.70^{b}	30.46±2.24^{b}	27.26±4.97^{b}	29.72±2.62^{b}	32.91±1.78^{ab}	38.08±0.34^{a}	28.80±1.50^{b}
20°C	29.82±3.19^{a}	29.77±2.44^{a}	32.11±0.78^{a}	30.99±2.16^{a}	30.68±1.81^{a}	29.82±4.84^{a}					
a* 4°C	4.67±1.18^{ab}	6.63±0.38^{a}	5.53±1.48^{bc}	4.54±0.61^{ab}	3.47±0.31^{a}	5.95±0.85^{bc}	5.68±0.11^{bc}	6.24±1.05^{a}	6.01±0.44^{bc}	6.38±0.91^{a}	6.99±0.29^{a}
10°C	4.69±2.27^{ab}	4.41±0.64^{c}	4.92±0.67^{ab}	5.88±1.03^{ab}	4.67±1.50^{ab}	5.10±0.67^{ab}	6.21±1.46^{ab}	5.82±0.55^{ab}	6.08±0.57^{ab}	6.98±0.60^{b}	5.17±1.12^{a}
20°C	6.53±0.90^{bc}	6.11±0.62^{c}	8.58±0.99^{bc}	8.26±1.11^{abc}	8.50±1.78^{bc}	6.53±1.69^{a}					

Data are mean ± SD.
^{abc}Different letters are significantly different (p<0.05) by Duncan's test.

Table 1(B). Change in inner colors of *Galbi-jjim* by *sous-vide*/cookchill system during storage

Inner color	Storage d										
	1 d	4 d	8 d	11 d	15 d	18 d	22 d	25 d	29 d	32 d	36 d
L* 4°C	32.11±2.66^{a}	34.68±0.76^{a}	34.34±5.29^{a}	36.99±4.55^{a}	34.78±1.64^{a}	34.03±3.69^{a}	36.88±1.25^{a}	35.74±3.31^{a}	33.31±5.40^{a}	34.23±2.98^{a}	33.96±1.14^{a}
10°C	38.27±2.92^{ab}	35.06±0.62^{b}	33.03±3.36^{bc}	35.34±3.65^{b}	25.47±3.7^{b}	33.21±2.24^{bc}	33.59±4.97^{bc}	29.13±2.62^{c}	37.17±1.78^{ab}	41.51±0.34^{a}	32.97±1.50^{bc}
20°C	36.19±3.58^{a}	35.64±2.84^{a}	37.72±2.56^{a}	35.76±2.64^{a}	34.45±1.17^{ab}	36.19±1.58^{b}					
a* 4°C	6.74±1.18^{a}	7.12±0.38^{a}	8.18±1.48^{a}	7.22±0.61^{a}	8.32±0.31^{a}	7.71±0.85^{a}	7.64±0.11^{a}	6.99±1.05^{a}	7.01±0.44^{a}	7.90±0.91^{a}	8.29±0.29^{a}
10°C	8.55±2.27^{b}	7.15±0.64^{bc}	8.16±0.67^{bc}	6.98±1.03^{bc}	7.91±1.50^{bc}	6.21±0.67^{c}	7.55±1.46^{bc}	8.08±0.55^{bc}	7.75±0.57^{bc}	7.45±0.60^{bc}	8.32±1.12^{a}
20°C	7.38±1.15^{b}	7.61±0.56^{b}	8.34±1.18^{b}	7.89±0.34^{b}	8.22±1.31^{b}	7.38±2.23^{a}					

Data are mean ± standard deviation
^{abc}Different letters are significantly different (p<0.05) by Duncan's test.

degradation of proteins during aging. The b^* values (yellowness) of *galbi-jjims* stored at 4°C for 4 d were significantly higher than 1 d, but decreased during storage (Data not shown).

Table 1(B) shows the change of the inner color in the SV/CC processed *galbi-jjim*. During storage, L^* (lightness) values and a^* (redness) values were not significantly changed at 4°C, whereas products at 10°C and 20°C were significantly changed ($p<0.05$). At 10°C, L^* (lightness) values of inner beef color significantly decreased for 15 d (38.27 to 25.47), but increased after 15 d and a^* (redness) values were slightly changed. At 20°C, L^* (lightness) values decreased and a^* (redness) values increased during storage.

Sensory analysis

The sensory qualities of *sous-vide galbi-jjim* were shown in Fig. 6. The vales of saltiness, meat color and meat flavor were significantly changed between 0 to 3 wk ($p<0.05$) but, the scores of ingredient color, meat texture, oxidized odor, off-flavor and off-taste, meat juiciness and overall acceptance were not changed during storage. Oxidized odor, off-flavor, off-taste values were increased, but not significantly changed ($p<0.05$). The scores of meat juiciness and overall acceptance were decreased during storage, but were not significantly different ($p<0.05$).

Microbiological analysis

Microbiological analysis of the samples stored at 4°C and 10°C were performed at the interval of 3 d for 36 d. At 20°C, samples were analyzed until 15 d because of swelling of packages. Generally, a high number of coliforms and detection of *E. coli* in food reflects poor hygienic handling during the production process, inappropriate storage conditions and post-process contamination (Ghazala *et al*., 1995; Keeratipibul *et al*., 2009). After being stored for 1 d, coliform and *E. coli* were not detected in any of the samples at 4, 10 and 20°C and it was demonstrated that SV/CC "*galbi-jjim*" was properly produced. At 4 and 10°C, microbial growth was not observed until 36 d (Fig. 7). Also, after storage at 20°C until 15 d, coliform and *E. coli* were not detected, even though packs were visibly swollen. In addition, Food-borne pathogenic bacteria (*Shigella* spp., *E. coli* O157:H7, *S. aureus*, *B. cereus*, *V. parahaemolyticus*, *L. monocytogenes*, *Y. enterocolitica*, *Salmonella* spp.) were not detected during storage at any temperature. These results are in agreement with those reported by Jang and Lee (2005), who also found similar aerobic and anaerobic bacteria growth in *sous-vide* Korean seasoned beef at 4°C and

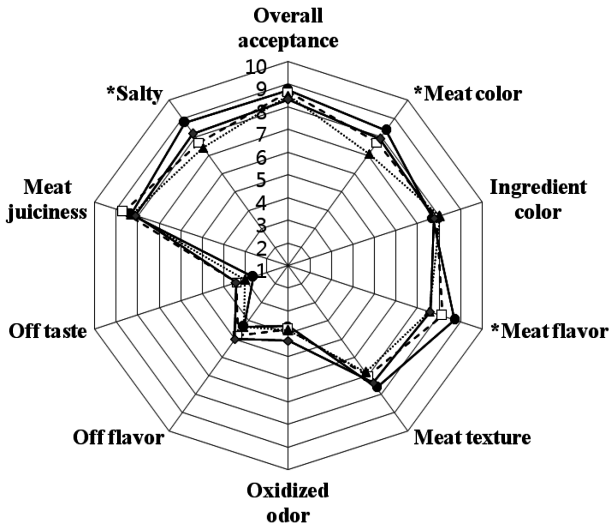

Fig. 6. Change in sensory quality of *Galbi-jjim* by *sous-vide*/ cookchill system during storage at 4°C. 0 wk (●), 1 wk (□), 2 wk (▲) and 3 wk (◇).

10°C during the storage, but, bacteria started to grow at 20°C after 9 d of storage. Also, Gonzalez-Fandos (2004) reported that other anaerobic or facultative anaerobic bacteria were found at 20°C during the storage. In general, since temperature abuses can happen during the products distribution, retail or consumer level, the storage temperature cannot guarantee microbiological safety of SV/CC products. Additional hurdles like low pH, a_w, and high NaCl contents should be applied. At 4, 10 and 20°C, other pathogenic bacteria except *Shigella* spp. were not detected during storage periods. However, *Shigella* spp. was detected after 36 d at 4°C and 10°C and 1 d at 20°C. Even though raw materials were appropriately stored (-20°C in vacuum packaging) and heat treatment was applied according to ACMSF (2004) and ECFF (1996) guidelines, samples can be contaminated during production due to utensils and environmental condition such as air. To ensure microbiological safety of *sous-vide* products in mass production, Hazard Analysis Critical Control Point (HACCP) system should be applied (Gonzalez-Fandos *et al*., 2004).

Conclusion

Our study has shown that the proper storage of vacuum-packaged and cooked *galbi-jjim* at 4°C and 10°C did not lead to the hygienic and pathogenic microbiological growth during storage. Also, the qualities in the physicochemical properties such as pH and water activity of *sous-vide* processed *galbi-jjim* were not changed during storage at 4°C and 10°C, and the sensory qualities were

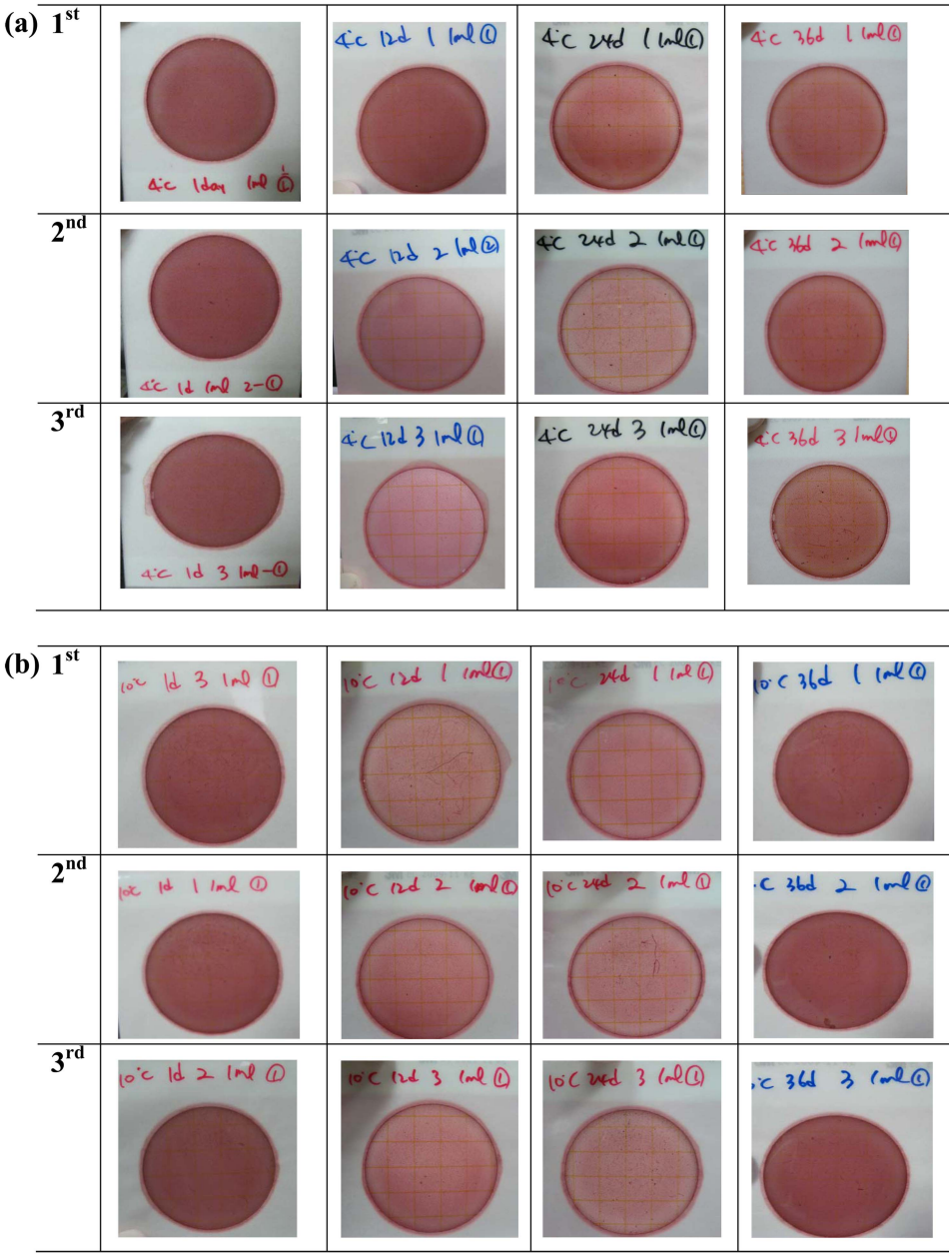

Fig. 7. ***E. coli*** **and coliform counts of** ***galbi-jjim*** **by** ***sous-vide*****/cookchill system for 36 d at 4°C (A) and 10°C (B).**

not affected by storage time and temperature. However, the TBARS values of *galbi-jjims* stored at different temperatures significantly increased with storage time ($p<0.05$). The hardness of *galbi-jjim* stored at 10°C and 20°C were lower at refrigerating temperature (4°C). This study suggested that *sous-vide*/cookchill processing can provide a microbiologically safe quality of RTE food products for a relatively long period.

Abbreviations

SV/CC, sous-vide and cook-chill; RTE, ready-to-eat; ACMSF, advisory committee on the microbiological safety of food; ECFF, european chilled food federation; DHSS, department of health and social security; PE, polyethylene; LLDPE, linear low density polyethylene; TBARS, thiobarbituric acid reactive substance; TBA, thiobarbituric acid; PCR, polymerase chain reaction; TBE, tris/borate/EDTA; HACCP, hazard analysis and critical control points.

Acknowledgement

This work was supported by a Korean Research Foun-

dation Grant funded by the republic of Korea Goverment (No. C00288).

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(Received 2010.4.19/Revised 2010.7.24/Accepted 2010.8.31)