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수비드 및 조리 냉각 시스템으로 준비된 한국 전통 “사태찜”의 품질 평가 (소사태)

Quality Evaluation of Korean traditional "Satae-jjim" prepared by sous-vide and cook chill system (Beef shine shank)

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Abstract
As society becomes industrialized, dietary habits shift toward convenience and frozen foods. Beef consumption has surged, with growing interest in cooking methods that enhance flavor and nutrition. "Satae," a less popular, tough beef cut near the bovine patellar region, shows improved taste when slow-cooked. In Korea, domestic beef contains higher vitamin A, E, and flavor-enhancing nucleic acids than imported beef. This study examines the storability of "Satae" using sous-vide cook-chill methods under temperature abuse conditions. Samples were vacuum-sealed, cooked at 90°C for 120 minutes, rapidly cooled to 3°C, and stored at 5°C or 15°C for 36 days. Physicochemical properties (pH, water activity, color parameters, salinity, texture profile analysis, volatile basic nitrogen and microorganism analyses (aerobic bacteria, *E. coli, coliforms*) were performed. Results showed significant changes in physicochemical properties during storage, though no substantial differences were observed. *V*olatile basic nitrogen values, however, increased rapidly after day 27, surpassing decomposition limits in the national Food Code. Microbial growth was insignificant at both temperatures. Based on *V*olatile basic nitrogen data, the product's storability was estimated at 31.7 days at 5°C and 23.8 days at 15°C, demonstrating the *S*ous-vide/cook-chill method's potential for extending shelf life while preserving quality.

Key words: *S*ous-vide/cook-chill methods, *Storability, Satae*, *V*olatile basic nitrogen
주제어: 수비드/냉각 법, 저장성, 사태, 휘발성 염기성 질

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Ⅰ. Introduction

Economic and societal developments have not only improved the quality of life but also transformed the dietary habits of households. As part of this transformation, consumer interest in precooked meals has grown significantly. Among these, frozen convenience foods have become increasingly popular among domestic consumers, prompting the food service industry to recognize their necessity (Lyu & Lee, 2001). In Western food service industries, partially processed foods are commonly packaged and stored frozen using the cook-chill method to achieve cost reduction, improved storability, and enhanced preparation efficiency (Greathouse et al., 1989; Spears, 2000). One notable advancement in this field is the sous-vide cooking technique, first developed by Georges Pralus in 1970s France, which involves vacuum-sealing food in heat-resistant plastic bags and cooking it at precise, low temperatures. This method is known for preserving food juices, ensuring even cooking, and enhancing tenderness, quality, and nutritional content (Varoquaux et al., 1995).

The sous-vide cook-chill system (SV/CC) has been widely adopted in internationally renowned restaurants, where fresh ingredients are vacuum-sealed with appropriate seasonings, cooked at below-boiling temperatures, rapidly cooled to below 3°C, and stored at low temperatures. The vacuum-sealing process eliminates oxygen, preventing lipid oxidation and allowing the natural flavors of ingredients to be preserved. Transparent films with low oxygen permeability are crucial for maintaining food quality, color, and nutritional value (Bailey, 1998; Church & Parsons, 2000). Additionally, vacuum packaging inhibits microbial decomposition, and cooking at sub-boiling temperatures serves as a sterilization process, effectively eliminating harmful bacteria such as Salmonella. For instance, cooking chicken breast at 71°C for 5 s or beef at 54°C for 86 min has been shown to eradicate bacterial contamination. To ensure food safety and longevity, proper freezing and refrigeration protocols must be strictly followed. While sous-vide technology has been extensively utilized in Western countries, its application in Korea remains relatively recent, with research focusing on recipe development and quality assessment for SV/CC traditional dishes such as instant steamed short ribs (Kim et al., 2009) and steamed chicken (Jeong, 2011). The growing interest in frozen convenience foods highlights the need for continued research and development in this field (Kim & Song, 2007; Song et al., 2007; Lyu & Lee, 2002; Lyu & Lee, 2004).

As national food consumption increases, meat consumption has also risen proportionally. Beef is an excellent source of animal protein and essential vitamins, including A, B1, and B2, and is widely consumed worldwide. In Korea, beef is highly valued for its low fat content, superior flavor, and tenderness. However, certain cuts, such as shin shanks, are less preferred due to their high connective tissue content, resulting in a tougher texture. Despite this, the SV/CC method effectively breaks down connective tissues, modifying the protein structure to enhance both flavor and texture. This process overcomes the disadvantages of shin shanks, increasing their usability and making them a cost-effective ingredient for processed foods.

Satae-jjim is a traditional Korean dish made from beef shank, requiring long cooking times to achieve tenderness due to its high muscle and tendon content. Recently, sous-vide techniques have been applied to its preparation, allowing precise temperature control to enhance texture and moisture retention. Protein denaturation occurs at different temperatures myosin at 50°C, collagen at 40°C, and actin at 66°C making sous-vide an effective method for optimizing tenderness. Additionally, rapid cooling after cooking is crucial for food safety and maintaining quality by preventing bacterial growth. The integration of sous-vide and cooling systems modernizes Satae-jjim while preserving its traditional flavors.

Building on previous studies, this study applies a modern SV/CC system to the traditional Korean dish "Satae-jjim," examining the effects of refrigeration temperatures and temperature fluctuations on its storability through physicochemical and biological analyses. Various storage conditions (5°C, 15°C) and durations were tested, with seven physicochemical and microbial experiments conducted to assess quality changes. By applying sous-vide techniques to an underutilized beef cut, this study aims to enhance its value and consumer appeal. The findings provide scientific evidence for developing high-quality, ready-to-eat traditional dishes, contributing to the growing demand for convenient, nutritious food options in modern society.

Ⅱ. Materials and Methods

1. Sample preparation

The material chosen for this study was Korean traditional *"Satae-jjim"*. *"Satae"*, a specific beef cut, was obtained by purchasing Korean beef from Seoul market square and the rest of the ingredients were acquired on the same day of the experiments and were immediately, maintaining the freshness. The recipe used for Korean traditional *"Satae-jjim"* were adjusted and supplemented with appropriate ingredients, quantities, duration, and temperatures established by preliminary experiments. The ingredients are as shown in <Table 1>.

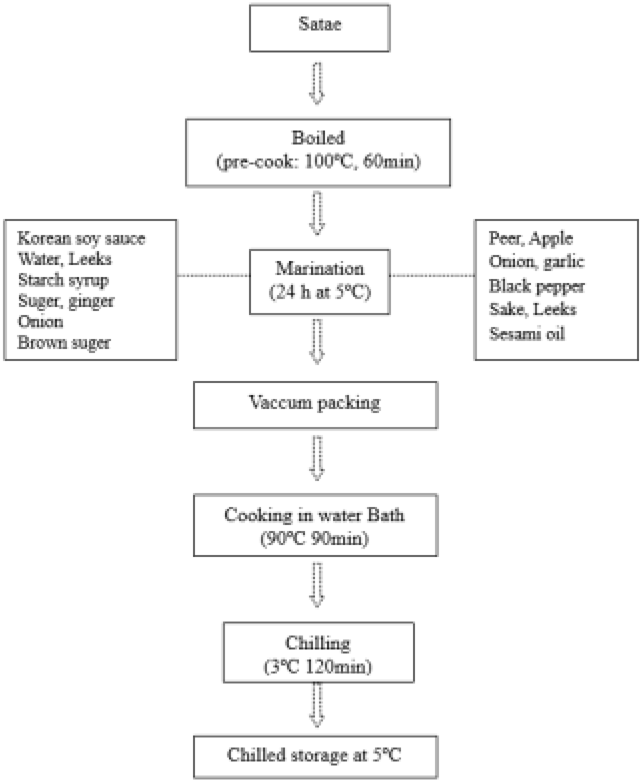
<Table 1> Formulation of *Satae-jjim*

Ingredients	Contents(%)
Korean soy sauce	13.79
Water	22.99
Green leaves	3.45
Starch syrup	2.30
Suger	2.30
Ginger (Sliced)	1.15
Onion (Sliced)	2.87
Brown suger	2.87
Korean pear	17.24
Koean apple	17.24
Onion (puree)	2.30
Garlic (puree)	2.30
Black pepper	0.57
White leaves	3.45
Sake	2.87
Sesame oil	2.30
Total	100

2. SV/CC processing of "Satae-jjim"

The cooking process for SV/CC-prepared Korean traditional *"Satae-jjim"* is illustrated in <Figure 1> *"Satae"* cuts obtained from the market were removed of blood by submerging in water for 2 h, replacing the water every 30 min. The rinsed *"Satae"* cuts were cooked for 60 min in boiling water and the sauce to be used for Korean traditional *"Satae-jjim"* was prepared with vegetables, fruits, and seasoning in Table 1. The cooked beef and sauce were both cooled down, and the *"Satae"* cuts were marinated in the sauce in the refrigerator (FRB-4230N, Daewoo, Seoul, Korea) at 5°C for 24 h. The marinated cuts were then vacuum-sealed in polyamide-polypropylene (Sealed Air Packaging Co,. Ltd, China) using a sealing machine (SH-100/SMV-206T, Samhosa Co., Ltd., Seoul, Korea), and were subsequently cooked at 90°C for 120 minutes in a water bath (JSWB-11T, JS Research INC., Gongju, Korea). The cooked samples were rapidly chilled at 3°C for 2 h within 30 min of cooking, and the procedures were carried out per microorganism quality guidelines to ensure protection against contamination.

The European Chilled Food Federation (ECFF, 1996) recommends that heat treatment equivalent to the 90℃ for 10 min (a z value of 7℃) process are 52 min at 85℃ or 270 min at 80℃, and according to the Advisory Committee on the Microbiological Safety of Food (ACMFS, 2004) equivalent to the 9 0℃ for 10 min (a z value of 9℃) process are 36 min at 85℃ 129 min at 80℃, 464 min at 75℃ or 1,675 min at 70℃.



<Figure 1> Preparation of Korean traditional "*Satae -jjim*" by SV/CC system

3. Physicochemical and microbiological Experiment

Quality assessment in this study using physico-chemical experimentation (proximate composition, pH, volatile basic nitrogen, color, water activity, TPA) was performed following previous domestic or international publications and codes.

All experiments excluding the ones for water activity (a_w) were spaced out in 3-day increments (Day 1, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36) for a total of 13 storage experiments and a_w measurements were done in 5-day increments for a total of 8 times. All experiments were repeated 3 or 6 times.

1) Proximate composition

Proximate composition of "*Satae*" was analyzed according to MFDS (2011). Briefly, moisture content was measured with atmospheric pressure heated drying method, protein with Kjeldahl method, crude fat with Soxhlet extraction method, and ash using a furnace with ash test and calculation method

2) Water activity (a_w)

Water activity (a_w) was measured with Conway unit method (Sibata Scientific Technology Ltd., Tokyo, Japan), and the experimental method was as following: 2 reagents of different a_w, potassium dichromate (reagent A, a_w 0.980) and potassium nitrate (reagent B, a_w 0.924), were placed into the internal chamber with 3g of each sample, and upon rapid collection, 1g of sample was placed into the external chamber at 25±2°C for 2 hours, and the resulting sample was weighed and calculated for a_w.

3) pH

For measuring pH, 5g of the food sample and 25ml of distilled water were homogenized using a blender (HMF-505, Hanil Electric Inc., Bucheon, Korea). The homogenized sample was filtered through Whatman No. 2 filter papers (Advantec No.2/TY2, Tokyo, Japan) and measured with a pH meter (Model M530 Pinnacle, Corning, USA).

4) Color

Colorimeter (Minolta CR-400, Minolta Co., Ltd., Japan) was used to assess the color of the sample surface after removing the packaging. A sample of Korean traditional "*Satae jjim*" was placed onto the analyzer. L^* (darkness to lightness), a^* (redness), and b* (yellowness) values were measured in triplets and averages were obtained. Calibration plate values for L^*, a^*, and b^* were 34.21, 94.50, and 31.93, respectively.

5) Volatile basic nitrogen (VBN)

Following Korean Food Codes (MFDS 2011), VBN measurements were carried out with the microdiffusion method using Conway unit. 10 g of sample were mixed with 50ml of distilled water and were filtered after leaching for 20 min. The filtrate was neutralized with weak acid H_2SO_4 and filled to 100 mL of experimental solution with distilled water. Slightly tilting the Conway unit, 1ml of the solution was placed into the bottom of the exterior chamber and 1 mL of 0.01 N H_2SO_4 was placed into the interior chamber in the same way. To provide an airtight seal, glycerin was evenly spread around the unit lid, and 1ml of K_2CO_3 saturation solution was added near the top of the exterior chamber quickly followed by the lid closure, which was then with fixed with a clip. The diffuser was tilted side-to-side to mix the experimental and saturating solutions well inside the exterior chamber and was left at 25°C for 1 h. Extra caution is needed to keep the solutions in the exterior chamber from mixing with the solutions in the interior chamber. After 1 h, the unit was reopened, one drop of Brunswik test solution was added into the H_2SO_4 solution in the interior chamber, which gave it a pink color, and the solution was then titrated using 0.01 N-NaOH solution until the color turned green. Distilled water instead of the experimental solution was also used for a blank test, and calculations were carried out as the following:

$$VBN(mg/\%) = \frac{0.14(mg/mL)*(b-a)*100*d}{W(g)} \qquad (1)$$

W : Weight of specimen collected (g)
a : Mol of 0.01 N NaOH solution consumed in titration
b : Mol of 0.01 N NaOH solution consumed in titration for blank test
F : 0.01 N NaOH titer
d : Dilution factor
0.14 : Quantity (mg) of volatile basic nitrogen (VBN) equivalent to 1ml of 0.01 N H_2SO_4 solution

6) Texture profile analysis (TPA)

To determine the textural properties of Korean traditional *"Satae-jjim"*, TA.XT 2i/25 (TA.XT 2i/25, Stable Microsystem, London, UK) was used. Samples for measurement were cut into sizes of 1.5 x 1.5 x 1.5 cm^3. Properties measured in increments of 3 days for a total of 13 times were: hardness, fracturability, adhesiveness, springiness, cohesiveness, gumminess, chewiness, and resilience, a total of 8 properties. Measurements were conducted using an aluminum cylinder probe P/50 diameter, and measuring conditions are followed as below: pretest speed 3.00 mm/s, test speed 1.00 mm/s, post-test speed 1.00 mm/s, strain 80%, time 2.00 sec and force 5.00 *g*.

7) Microbiological analysis

Microorganism analysis was performed using petrifilm (PEC) (3M, St. Paul, MN, USA) according to instructions of manufacturer. Aerobic bacteria measurement was done with petrifilm Aerobic Count Plate, coliform bacteria with petrifilm Coliform Count Plate, and *E. coli* with petrifilm *E. coli/* coliform Count Plate. To confirm the presence of microorganisms, 225ml of 0.1% sterile peptone water (Difco, USA) was homogenized with 25 g of sample for 2 min using a grinder (BagMixer®400, Interscience, France), and the homogenate was diluted with 0.1% sterile peptone water. To measure aerobic bacteria, the overlying film was removed, and 1 mL of the drying medium was aliquoted for each sample dilution, for which the inoculated sites were then pressed with the pressor and subsequently cultured at 35°C for 24 h. Generated red colonies were then calculated based on the dilution to obtain the actual number of aerobic bacteria. coliform bacteria and *E. coli* were quantified and corrected for dilution in the same way except that the red colonies with observed gas bubble production were used for coliform bacteria and green colonies with observed gas bubble production were used for *E. coli*.

8) Shelf-life determination

In order to obtain the shelf-life, product quality was assessed at different dates after setting the two storage temperatures at 5°C and 15°C with a large difference of 10°C between them. At both temperatures, pH, VBN, and other physicochemical characteristics were measured, and ones with significant changes were selected as product quality indicators. The shelf-life of *"Satae-jjim"* was, therefore, defined by multiplying the experimentally determined period of edibility by a safety factor of 0.8.

9) Statistic analysis

Statistical significance for the results from 36 days of experimentation was assessed with analysis of variance (ANOVA) using SPSS version 18.0 (SPSS Inc., Chicago IL, USA). In the case of significance with $p<0.05$, results were further verified with Duncan's multiple range test.

III. Results and Discussion

1. Proximate composition

Proximate composition of the specific cut, *"Satae"*, from Korean beef was as shown in <Table 2> Moisture, protein content, fat content and ash were obtained as 73.72%, 20.55%, 4.01%, and 0.99%, respectively. Bovine muscles alter in their moisture content under stress, thereby also affecting the beef quality, and freeze-thaw processes may also produce changes in the beef quality. Therefore, it can be suggested that the relationship between moisture and beef quality is a rather close one.

<Table 2> Proximate composition of *Satae*

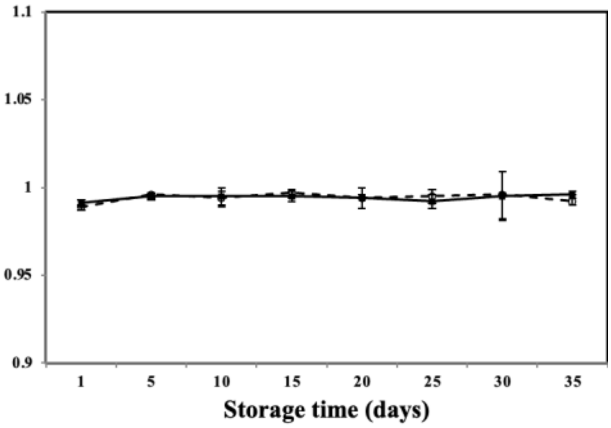
Moisture	Protein	Fat	Ash
73.72±0.58	20.55±0.60	4.01±0.47	0.99±0.02

2. Water activity(a_w) and pH

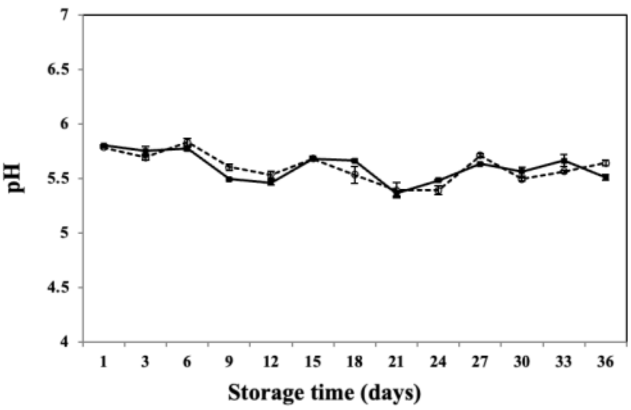
Water activity was measured from day 1 in 5-day increments and pH was measured at days 1, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, 36. The changes in water activity and pH values between 5°C and 15°C are shown in <Figure 2>.

Initial a_w values at 5°C and 15°C were 0.989 and 0.991, respectively. At 5°C, day 15 showed the highest a_w, and at 15°C, a_w was 0.996 on the day 35. With regards to a_w, the optimal level for aerobic bacteria growth is 0.85. In this study, a_w ranged from 0.989 to 0.997 and since it is still within the range viable for bacterial growth, it suggests that there is risk for microorganism proliferation (Gilbert et al., 1997).

Results from pH changes are shown in <Figure 3>. At 5°C, the highest pH measurement was obtained on day 6 with the value of 5.83 and at 15°C, a maximum of 5.8 was obtained on day 1. Based on a previous study, a pH between the range of 5.5-5.8 would be considered of a fresh condition but would be considered undergoing decomposition at pH beyond 8.0 (James MJ, 1972). In this study, the range of pH throughout the duration of storage at 5°C and 15°C was 5.39-5.83, and thus fell into neither the range of possible decomposition nor the range of 6.8-7.2 that favors microorganism growth.



<Figure 2> Change in a_w of Korean traditional "*Satae-jjim*" by sous-vide and cook-chill system during storage at 5°C (○) and 15°C (■) vertical bars indicate standard deviations.



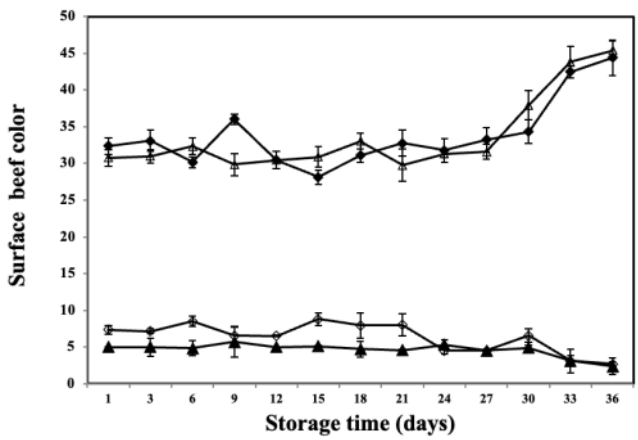
<Figure 3> Change in pH of Korean traditional "*Satae-jjim*" by sous-vide and cook-chill system during storage at 5°C (○) and 15°C (■) vertical bars indicate standard deviations.

3. Color

Results from the surface appearance of *"Satae-jjim"*, the traditional Korean plate cooked by

SV/CC system, are shown in <Figure 4>.

Changes in the heat-cooked meat color have been demonstrated to be related to levels of nitric oxide and myoglobin, degrees of globin or hemo-chrome production, presence/levels of oxygen, storage temperature, packaging method, pH, and pressure (Cornforth et al., 1994). L^* values, at both 5°C and 15°C, were significantly different from baseline in association to the duration ($p<0.05$). At 5°C, L^* values repeatedly increased and decreased until the 33^{rd} day, on which it increased to 42.47 and at 15°C, it increased from the 30^{th} day until the last day (36^{th}) on which it was measured at 45.45. Redness represented by *a** did not show significant changes but as time progressed beyond the storage period, they trended downward until the last day on which the values were 2.7 and 2.39 at 5°C and 15°C, respectively. Yellowness represented by *b** values also repeatedly increased and decreased at both 5°C and 15°C. At 5°C, the final value on the 36th day was lower at 9.30 than the initial value of 10.74. In contrast at 15°C, the value on the last day was higher at 13.03 than the initial value of 9.03 (*b* values data not shown).



<Figure 4> Change in surface color of Korean traditional "*Satae-jjim*" by sous-vide and cook-chill system during storage. 'L*' value at 5°C (◆), 15°C (△); 'a*' value at 5°C (◇), 15°C (▲). Vertical bars indicate standard deviations.

4. Volatile basic nitrogen (VBN)

Changes in the VBN measurements of "*Satae-jjim*", the traditional Korean plate cooked by SV/CC system, are as shown on <Figure 5>. VBN is commonly used as a standard method to determine the freshness of meat or fish protein and also serves as an indicator of quality. In varying storage temperatures and durations, VBN measurements were similar early on but displayed greater differences as storage duration progressed. At 5°C, the measurement on the first day was 8.51 mg/%, the lowest of all measurements at either temperature, and last day was 17.81mg/% ($p<0.05$). At 15°C, from the 27^{th} day of storage, VBN rapidly increased to 24.88 mg/%, a value exceeding the levels of early decomposition ($p<0.05$). According to a previous study, as VBN increases, nonprotein nitrogen compounds that are produced upon aging provide a particular taste and scent (Dierick et al., 1974), and another study reported that VBN compounds are produced as ammonia and elements degraded by *Pseudomonas spp.* and other Gram negative bacteria that often contaminate meat products (Lefebvre et al., 1994). Day 36, the last day of storage, showed a value of 25.85 mg/%, which was the highest in the experiment.

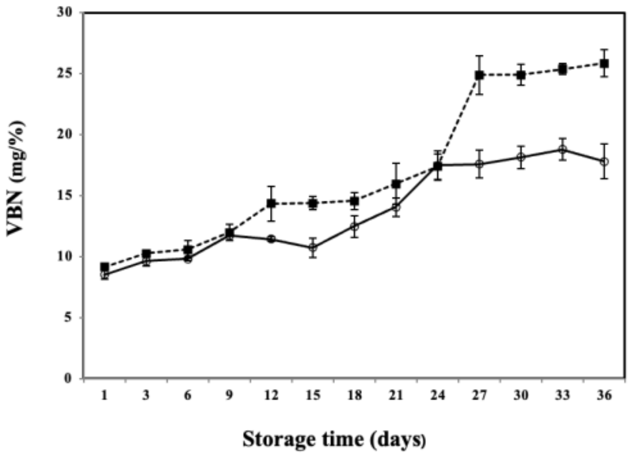
When the freshness in meat or fish drops, VBN significantly increases, and the national Food Code has set the approved maximum value of VBN at 20% for raw meat or packaged meat. It also reported that at VBN levels above 15 mg/%, detecting the decomposition of beef becomes possible.

Furthermore, it has been previously reported that at VBN levels above 15 mg/%, decomposition can be sensed, but in this study, the level after which an ordinary person could detect decomposition was not reached even with VBN above 20 mg/%. To evaluate the detection of decomposition more accurately, the addition of an electric nose device may be necessary.

5. TPA

Results of the TPA measurements of "*Satae-jjim*", the traditional Korean plate cooked by SV/CC system, on days 1, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, and 36 are as shown in <Figure 6>.

Throughout the storage duration at 5°C, hardness significantly changed from the initial value of 16.55 to 11.40 by the 36th day (p<0.05). From the 9th day, it appeared to increase, but it began to decrease again from the 15th day. Similar to hardness, gumminess and chewiness values also decreased significantly compared to their baseline. fracturability, adhesiveness, springiness, cohesiveness, and resilience did not change significantly. At 15°C, hardness continuously decreased without an up-going trend (p<0.05). Adhesiveness, springiness, cohesiveness, and resilience did not show significant changes. Díaz et al., (2008) have reported that these changes are influenced by connective tissue content, sarcomere lengths, and degree of protein degradation.



<Figure 5> Change in VBN of Korean traditional "*Satae-jjim*" by sous-vide and cook-chill system during storage at 5°C (○) and 15°C (■) vertical bars indicate standard deviations.

6. Microorganism

Microorganism analysis of "*Satae-jjim*", the traditional Korean plate cooked by SV/CC system, were carried out on day 1, 3, 6, 9, 12, 15, 18, 21, 24, 27, 30, 33, and 36 under 5°C and 15°C. Microorganism counts of 1.0 x 10^6 CFU/cm^2 or 1.0x10^7 CFU/cm^2 in vacuum-sealed meats are considered to represent early stages of decomposition and counts of 1.0 x 10^8 CFU/cm^2 or 1.0 x 10^9 CFU/cm^2 allow for formulation of mucous substances along with changes in color and strong signs of decomposition (Brown, 1982; Nottingham, 1982).

Throughout the entire storage duration at 5°C or 15°C, the presence of coliform or *E.coli* bacteria was not detected. This showed that the packaging and storage processes of "*Satae-jjim*" were carried out aseptically. Even if heat treatments were performed following the ACMSF (2004) and ECFF (1996) guidelines, various bacteria (*L. monocytogenes, Y. enterocolitica, and Aeromonas*) can lead to re-contamination and the microorganism proliferation can differ based on their type, storage temperature, composition of food, and form of packaging.

Based on a published study (Kim, 1998), as a result of vacuum-packaging marinated ribs, the product quality was preserved throughout the entire storage duration. In common, marinated meats sealed in vacuum could be stored for over 30 days without proliferation of microorganism and thus extend the shelf-life. However, while these systems may extend food shelf-life, they may still increase microbiological risk. Thus, such systems should be controlled by Hazard Analysis and Critical Control Point (HACCP).

7. Shelf-life determination

Shelf-life is considered as the period from point of product packaging to point of viable consumer purchase. It is necessary to determine the appropriate shelf-life of products because it identifies the point after which a manufacturer's product can no longer be sold. Factors that affect shelf-life of a product can be divided into internal and external factors. Internal factors include product formulation, composition, a_w, pH, and oxygen availability whereas external factors include level of sanitation, packaging materials, packaging method, distribution, and storage (temperature, humidity) conditions. According to a study by Newton and Rigg (Newton et al., 1979), shelf-life of a packaged meat is determined by storage temperature, storage duration, and packaging gas permeability.

VBN measurements showing in <Figure 5>

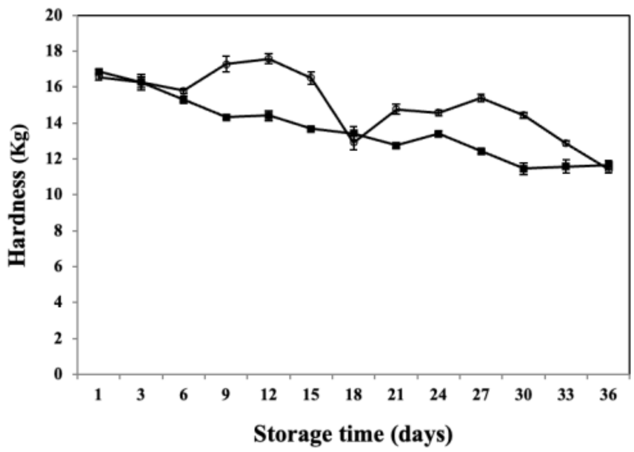
demonstrate that values increase as storage duration increases. At 15°C, from day 27, the value exceeded the standardized threshold of 20 mg/% per national Food Codes, and it was reasonable to consider VBN as a quality indicator of *“Satae-jjim”*.

(1) Q10 = storage duration at 15°C (days) / storage duration at 5°C (days)
(2) Shelf-life at standard temperature (10°C) D= storage duration at each temperature (days) x a^n
(3) Edible period x 0.8 (safety factor) = shelf-life

As shown above, formula (1) and (2) are used to calculate the edible period, finding 39.6 days at 5°C, and 29.7 days at 15°C. However, for better assurance of safety, determined storability is typically adjusted to a shorter period than the measured duration by using the safety index of 0.7-0.9 for calculation. In this experiment, to calculate the appropriate shelf-life for storage or sale, the safety index of 0.8 was multiplied to the measured duration, resulting with 31.7 days at 5°C and 23.8 days at 15°C. Furthermore, according to studies on the traditional Korean dishes, “Galbi-jjim” (Kim et al., 2009) and “JJim-dak” (Jeong, 2011), prepared with the SV/CC system, the storability was determined to be 15 days without using the safety index factor, and this observed disparity from our study may be due to the difference in the material used for packaging.

The expiration dates reported on products are, however, representative of the storability for sale, not consumption, and thus suggests that our intake of foods slightly beyond the reported dates may not be significantly affected. In 2009, the Korea Consumer Agency experimented on the changes in the product quality beyond the expiration date using milk (3 types), dairy beverages (4 types), and cheese (2 types). Aerobic bacteria and coliform bacteria were not detected in milk even 50 days beyond the expiration date. Similarly, dairy beverages or cheeses were not positive for aerobic or coliform bacteria even at 30 days and 70 days, respectively, beyond the expiration date. This experiment demonstrated that the expiration date does not necessarily indicate the time point at which the product quality alters. Nonetheless, manufacturers still set the expiration dates to be relatively short because of the consumers' preference. According to the research by Korea National Council of Consumer Organization, the most important indicator that the consumer examines prior to purchase is the expiration date as reported by 25.4% among 1,500 people, and was higher than the cost of the products. In overseas markets as in the U.S., aside from truly sensitive products such as powdered milk for infants, companies determine the expiration date as they see fit, and instead of the phrase, expiration date, they often utilize various expressions to describe storability.

Thus, in Korea also, other phrases such as consumable period or product quality period should be applied to indicate storability with less rigid or negative overtones.



<Figure 6> Change in hardness of Korean traditional “*Satae-jjim*” by sous-vide and cook-chill system during storage at 5°C (○) and 15°C (■) vertical bars indicate standard deviations.

IV. Conclusion

This study demonstrated that the sous-vide (SV) and cook-chill (CC) systems effectively preserved the quality and extended the shelf life of the traditional Korean dish, Satae-jjim (braised beef shank). Physicochemical and microbiological analyses confirmed that the safety and quality of the product were consistently maintained under controlled conditions.

By cooking at 90°C for 120 min under vacuum packaging, the sous-vide process minimized moisture loss and oxidation while effectively preserving the natural flavor of the meat. The SV process also significantly influenced the physical properties of Satae-jjim. Hardness measurements showed a gradual decrease from an initial value of 16.55 to 11.40 over 36 days of storage at 5°C, indicating the breakdown of connective tissues and muscle structures. Notably, tenderness increased significantly after 15 days of storage, suggesting that the SV process optimized texture by maintaining a balance between protein denaturation and water retention.

In terms of physicochemical properties, pH and water activity (Aw) did not exhibit significant ($p<0.05$) effects on storability at either 5°C or 15°C, and salinity remained consistent with baseline levels throughout the storage period at both temperatures. Regarding volatile basic nitrogen (VBN), levels during storage at 5°C increased slightly but never exceeded the threshold level of 20 mg% set by the National Food Codes. However, at 15°C, VBN levels rapidly increased to 24.88 mg/% after 27 days, surpassing the threshold. Microbial experiments confirmed the absence of aerobic bacteria, coliforms, and E. coli at both storage temperatures throughout the study.

In conclusion, the storability of Satae-jjim was determined to be 31.7 days at 5°C and 23.8 days at 15°C, demonstrating the effectiveness of the sous-vide and cook-chill systems in preserving its quality and ensuring food safety under controlled conditions.

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