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## Comparison of Single and Double Combination of Temperature-time in Sous Vide Treated Semitendinosus Muscle from Cattle and Goat

Ishamri Ismail<sup>1,2</sup>, Young-Hwa Hwang<sup>3</sup>, and Seon-Tea Joo<sup>1,3,\*</sup>

<sup>1</sup>Division of Applied Life Science (BK21<sup>+</sup>), Gyeongsang National University, Jinju 52828, Korea

<sup>2</sup>Faculty of Bioresources and Food Industry, Universiti Sultan Zainal Abidin, Besut Campus, 22200, Terengganu, Malaysia

<sup>3</sup>Institute of Agriculture & Life Science, Gyeongsang National University, Jinju 52828, Korea

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\*Corresponding author : Seon-Tea Joo  
Division of Applied Life Science (BK21Plus),  
Gyeongsang National University, Jinju 52828,  
Korea  
Tel: +82-55-772-1943  
Fax: +82-55-772-1949  
E-mail: stjoo@gnu.ac.kr

\*ORCID  
Ishamri Ismail  
<https://orcid.org/0000-0003-4820-8292>  
Young-Hwa Hwang  
<https://orcid.org/0000-0003-3687-3535>  
Seon-Tea Joo  
<https://orcid.org/0000-0002-5483-2828>

**Abstract** This study observed the effects of the double combination of temperatures-times (2 temperatures: 2 times combination, 2T2T) in sous vide cooking method on the physicochemical properties and collagen solubility (CS) of semitendinosus muscle from cattle and goat as a comparison to common sous vide treatment (1 temperature: 1 time combination, 1T1T). The new invention of sous vide cooking method (2T2T) cooked at the first temperature at 45°C for 3 h, and the second temperature at 60°C, 65°C, and 70°C for 3 h, and labeled as N45-60, N45-65, and N45-70, respectively. While, common sous vide treatment (1T1T) were cooked directly for 6 h at 60°C (T60), 65°C (T65), and 70°C (T70). Results revealed that cooking with 2T2T treatment improved the water-holding capacity and reduced the cooking loss of both beef and goat meat. The L\* values have no apparent changes between treatment in beef and goat meat, while a\* values of N45-60 treated goat presented markedly higher values than other treatments but an only slight increase in beef at the same treatment ( $p>0.05$ ). Again, 2T2T treatment tended to decrease mean shear force (SF) values for beef and goat meat with the lowest SF values recorded at N45-60, and the CS no or less influenced this value. Therefore, the application of innovative sous vides cooking method (2T2T) presented comparable values in the treated beef and goat meat as compared to common sous vide method (1T1T).

**Keywords** sous vide, low temperature-long time, beef, goat meat, tenderness

### Introduction

The application of low temperature-long time in sous vide cooking technique can be considered as another alternative of cook and chill catering technology in the last 10 years because this technique received considerable attention both from chefs and researchers (Baldwin, 2012). This technique is gaining in popularity in the catering

industry due to the consistency along the muscle and uniform appealing texture and color properties of the meat after thermal treatment (Christensen et al., 2012). Consumers are demanding cooked meat which has good in eating quality, and this quality is strongly influenced by the cooking method (Pathare and Roskilly, 2016). The mild process and the absence of oxygen in the preparation of sous vide meat is the main factor to give more benefit in eating quality (increased tenderness, improved color retention, texture, and flavor) than conventionally cooked meat (Baldwin, 2012).

Quality characteristics of cooked meat are dependent on the heating method, time/temperature evolution during cooking as well as the composition and characteristics of the muscles (Christensen et al., 2000). Meat undergoes physical and chemical changes during heating, including weight loss, loosening of water-holding capacity, texture and color modification, muscle fiber shrinkage, and aroma development (Walsh et al., 2010). These changes are an indicator the degree of denaturation of proteins and disintegration of membranes upon heating as well as the degree of cooking loss (CL) and fat loss that could affect the production yields in cooked meat products (Bowker and Zhuang, 2013).

In sous vide cooking the raw meat is commonly cooked under controlled temperature and time inside heat-stable vacuum packaged (Schellekens, 1996). The temperature applied is single thermal at a low temperature which is below 100°C and range of time 2 to 48 h (Vaudagna et al., 2002). The majority of papers focus only on the combination of single temperature-time (1 temperature: 1 time combination, 1T1T), as that is the most common and simple sous vide cooking method. However, the use of a double combination of temperatures-times (2 temperatures: 2 times combination, 2T2T) in sous vides cooking method and the effects towards meat quality has not yet been published. Thus, the objective of this study was to compare the effect of innovative sous vide (2T2T) with a common sous vide cooking method (1T1T) on beef and goat meat semitendinosus muscles by means of physicochemical parameter evaluation.

## Materials and Methods

### Animals

Bovine semitendinosus muscles (breed: Hanwoo steer carcasses with 3 quality grade; age: 31–32 months, 2-day postmortem, muscle pH at the time of purchase: 5.60–5.70) were purchased from a local market Jinju, Korea, and they were immediately transported to the Laboratory of Meat Science of Gyeongsang National University. The meat was kept cool at 4°C in the refrigerator for 2 h prior to analysis. Goat semitendinosus muscles (breed: Korean native black goat [*Capra hircus coreanae*]; age: 16–18 months: 2-day postmortem, muscle pH<sub>24</sub>: 6.32–6.53) were obtained from a homogenous production batch of the uncastrated male goat. The goat meat handling procedure after sample collection were similar as described in beef samples.

### Sampling and heat treatment

Both muscles were cut into total 18 parts with the same size (beef: 110±10 g/slice; goat: 80±10 g/slice). After removing the visible fats, ligaments and connective tissues, they were randomly divided into six groups for each of the three replicated experiments. Treatment consisted of 1) common sous vide cooking method with single temperature-time combination (1T1T), that was treated at 60°C, 65°C, and 70°C for 6 h and labeled as T60, T65, and T70, respectively; 2) innovative sous vide with double temperatures-times combination (2T2T), that was treated with the first temperature at 45°C for 3 h, and the second temperature at 60°C, 65°C, and/or 70°C for 3 h and labeled as N45-60, N45-65, and N45-70, respectively. All samples were vacuum packaged and they were cooked using a sous-vide immersion cooker (Travellortech precision cooker

immersion, USA). In addition, three other parts of cattle and goat muscles were used for performing analyses of fresh meat. Once the cooking process was finished, bags were transferred into icy cold water (1°C) for 1 h to avoid overheating process, and subsequently, all packaged were kept under refrigeration at 4°C overnight prior to analysis.

The day after the cooking process, samples were weighed before and after cooking to measure the percentage of CL. The CL fluid was then collected, centrifuged at 3,000×g at 4°C for 15 min, and subsequently frozen at –80°C for later measurement of CS as described by Christensen et al. (2011). Moisture content, water-holding capacity (WHC), color properties, and Warner-Bratzler shear force (SF) features were measured. The rest of the sample was kept in a freezer (–80°C) until analysis.

### Physicochemical properties measurement

Moisture content was quantified by oven-drying with 4 g of meat samples at 105°C for 16 h (AOAC, 2002). Water-holding capacity (WHC) was calculated from the method described by Joo (2018). Color determination of samples was carried out using a Minolta Chromameter (Minolta CR-300, Tokyo, Japan) equipped with a standard illuminant D65 and a pulse xenon lamp with 8 mm of reading surface area. L\* (lightness), a\* (redness), b\* (yellowness) values were recorded. The analysis of Warner-Bratzler SF was based on AMSA guidelines (AMSA, 1995). Sample cores (1 cm diameter) were removed parallel to the myofiber and the cores were sheared perpendicular to the myofibers orientation using the Instron tensile testing (Instron 4443, Norwood, USA). Peak force was obtained using 100 N load cell at a crosshead speed of 250 mm/min. Maximum peak force recorded as SF value.

### Soluble collagen in cook loss

The soluble collagen in the liquid samples was measured by modified methods of Kolar (1990). The frozen CL fluid was thawed overnight at 4°C and centrifuged at 3,000×g for 30 min at 4°C. Then 5 mL of supernatant was hydrolyzed with 30 mL of 3.5 M H<sub>2</sub>SO<sub>4</sub> at 105°C for 16 h. The hydrolyzed solution was diluted with distilled water (first to 100 mL, then to 50 mL), and measured for hydroxypropylation concentration as described for total collagen. Collagen solubility (% soluble collagen in the CL) is expressed in Eq. 1.

$$\% \text{ Collagen solubility} = \left( \frac{\text{Soluble collagen in cook loss, g}}{\text{Total collagen of raw meat, g}} \right) \times 100 \quad (1)$$

### Statistical analysis

Data were analyzed by one-way ANOVA as the sole source of variation and a Duncan test for multiple mean comparisons. Pearson correlation analysis was used to establish a linear relationship between measurements. All statistical analyses were performed using measurement means and standard deviation with the SPSS version 23 (IBM Corp., SPSS, Statistic). SF, collagen solubility (CS), and CL of cooked samples were pooled and compared using Principal Component Analysis (PCA) (PAST 3.21 software). Each trial was run in triplicate.

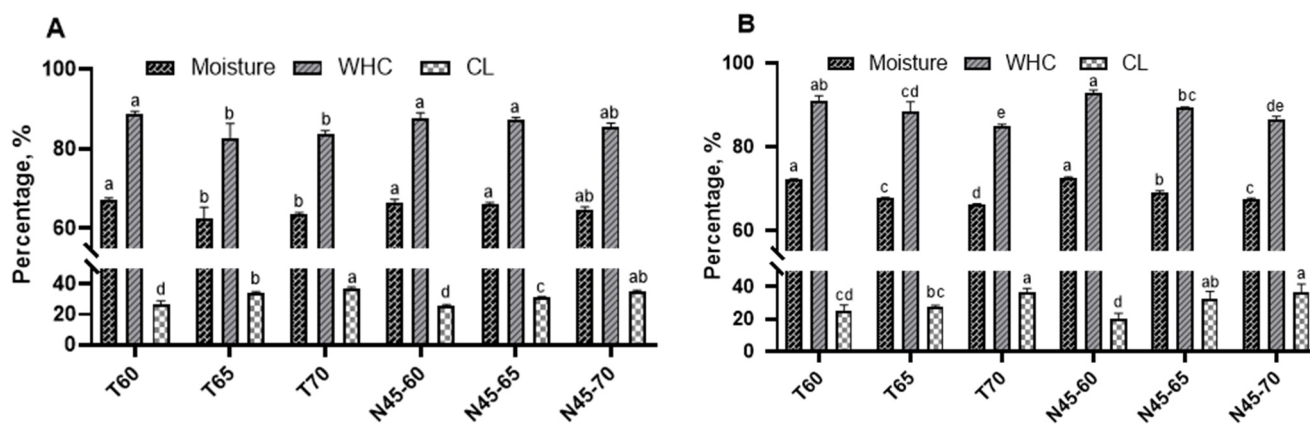
## Results and Discussion

### Moisture content, water-holding capacity, and cooking loss

This study investigated the combined effect of heating temperature-time between 1T1T (T60, T65, and T70) and 2T2T (N45-60, N45-65, and N45-70) in sous vide cooking on meat quality of semitendinosus from cattle and goat muscle. The results of the moisture content, WHC and CL are displayed in Fig. 1. As the temperature increased, moisture and WHC decreased, and CL increased for both beef and goat meat. Although there is no significant difference between heat treatment between 1T1T and 2T2T, innovative sous vide represents slightly better in the moisture content and WHC, as well as lower CL. According to Ismail et al. (2019), samples cooked for less time showed lower water loss than samples cooked with extended time. This reflects the cooking time in innovative sous vide method at the second temperature (60°C, 65°C, and 70°C) which were only cooked for 3 h as compared to common sous vide method which was cooked continuously at 60°C, 65°C, and 70°C for 6 h. Similar findings also were obtained by Christensen et al. (2013) in cows and young bulls and Roldan et al. (2013) in lamb loins.

### Color properties

The results of the color assessment of the sous vide cooked beef and goat meat is displayed in Table 1. All the color values



**Fig. 1.** Means of moisture content, water-holding capacity (WHC), and cooking loss (CL) of beef (A) and goat meat (B) heated at different temperature-time combinations.

**Table 1.** Means of color properties  $L^*$ ,  $a^*$ , and  $b^*$  values of beef and goat meat heated at different combination temperatures and time

	T60	T65	T70	N45-60	N45-65	N45-70
Beef						
$L^*$	60.27±0.93 <sup>a</sup>	61.01±1.07 <sup>a</sup>	60.13±0.98 <sup>ab</sup>	58.51±0.74 <sup>bc</sup>	61.20±1.25 <sup>a</sup>	57.92±0.30 <sup>c</sup>
$a^*$	15.05±0.78 <sup>a</sup>	11.64±0.14 <sup>b</sup>	11.83±0.47 <sup>b</sup>	15.75±0.91 <sup>a</sup>	12.22±0.41 <sup>b</sup>	12.67±0.49 <sup>b</sup>
$b^*$	8.61±0.87 <sup>c</sup>	9.84±0.65 <sup>ab</sup>	10.49±0.28 <sup>a</sup>	9.40±0.30 <sup>bc</sup>	7.30±0.57 <sup>d</sup>	10.09±0.25 <sup>ab</sup>
Goat						
$L^*$	62.66±0.68 <sup>b</sup>	64.49±0.50 <sup>a</sup>	55.29±0.06 <sup>c</sup>	54.88±0.50 <sup>c</sup>	55.27±0.67 <sup>c</sup>	51.57±0.40 <sup>d</sup>
$a^*$	13.32±0.63 <sup>d</sup>	14.08±0.64 <sup>c</sup>	11.59±0.20 <sup>e</sup>	23.80±0.02 <sup>a</sup>	15.36±0.26 <sup>b</sup>	12.09±0.09 <sup>e</sup>
$b^*$	8.95±0.62 <sup>d</sup>	7.58±0.48 <sup>e</sup>	12.16±0.17 <sup>b</sup>	13.43±0.24 <sup>a</sup>	12.08±0.13 <sup>b</sup>	10.83±0.12 <sup>c</sup>

All values are mean±SD.

<sup>a-c</sup> Means within a row within different letters are significantly different ( $p < 0.05$ ).

were affected by temperature and cooking method. Sous vide cooked samples treated at 65°C (T65 and N45-65) showed higher  $L^*$  values than those treated at 60°C and 70°C for both meat (beef and goat meat) and cooking method (1T1T and 2T2T). Other authors have found just the opposite results with the  $L^*$  values increasing with temperatures (Christensen et al., 2011; Garcia-Segovia et al., 2007). Meanwhile, Sanchez del Pulgar et al. (2012) and Roldan et al. (2013) have reported higher  $L^*$  values at 60°C than 80°C in pork and lamb, respectively. Our results seem to agree with both findings. First, the  $L^*$  values increase with the temperature increase from 60°C to 65°C. Second, 60°C showed higher  $L^*$  values than 70°C in beef ( $p>0.05$ ) and goat meat ( $p<0.05$ ). We empirically observed that those samples cooked at the temperature more than 65°C showed lower  $L^*$  values. Based on our findings in other study, samples of bovine semitendinosus cooked with low temperature-long time at 75°C has lower lightness values than at 70°C.

The  $a^*$  values represent the concentration of myoglobin or degree of myoglobin denaturation (Vaudagna et al., 2008). The redness of cooked meat is highly dependent on the myoglobin denaturation and end-point temperature of cooking (Lawrie, 1998). Goat meat samples treated with 2T2T had significantly higher red color than 1T1T treatment, but beef samples have no difference in  $a^*$  values between treatments. Nevertheless, beef samples with the double combined effect of heating temperatures-times showed slightly higher  $a^*$  values than single temperature-time treatment. The extensively higher of  $a^*$  values were most pronounced in goat meat at 45°C–60°C (N60) and might be associated to the lower CL, suggesting less extraction of denatured myoglobin in the CL liquid. Similarly, beef samples T60 and N45-60 cooked at 60°C showed the lower CL and represent higher redness values. Furthermore, the  $a^*$  values of beef and goat meat decreased with increasing temperature and this finding is in line with Christensen et al. (2011) in pork samples. On the other hand,  $b^*$  values showed a very variable behavior with the cooking conditions and the cause of the changes are complicated to elucidate.

### Shear force and collagen solubility

The effects of 1T1T and 2T2T treatment on beef and goat meat SF and CS are shown in Fig. 2. Sous vide 2T2T treatment tended to decrease mean SF values for beef and goat meat with the lower values recorded by N45-60 treatment. Surprisingly, the trend of SF values for both beef and goat meats showed a similar pattern for each temperature of both treatments (1T1T

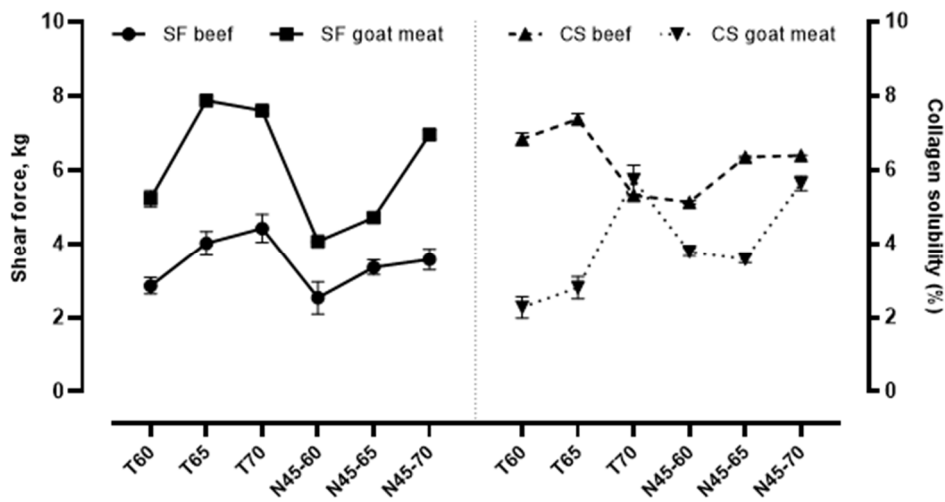


Fig. 2. Means of Warner-Bratzler shear force (SF) and collagen solubility (CS) of beef and goat meat heated at different temperature-time combinations.

and 2T2T). Obviously, semitendinosus muscle from Hanwoo steers was less tough than semitendinosus muscle from Korean native black goat. However, specific findings to elucidate major factors that cause 2T2T treated meats tender are not fully understood yet. In the present study, CS had less effect in tenderizing beef and goat meat by sous vide cooking method either 2T2T or 1T1T because it showed discrepancies in the CS towards SF values.

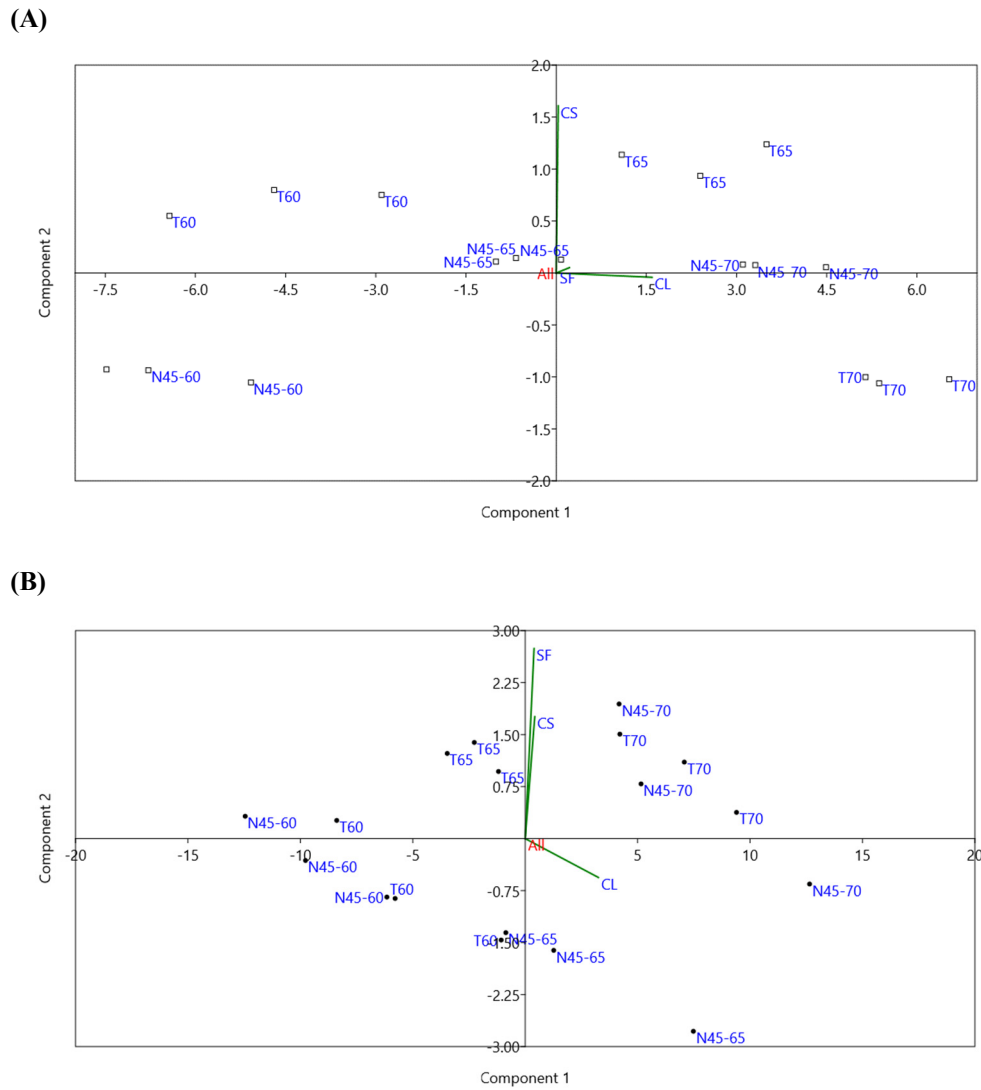
The lower toughness of combine temperature-time in 2T2T treatment might be attributed by double thermal effect. In our previous study, beef semitendinosus treated with low temperature-long time at 45°C showed the lowest SF values (Ismail et al., 2019). According to Myhrvold et al. (2011) and Lawrie (1998), the tenderness of cooked meat can be achieved at cooking temperature 45°C and 49°C even cooked for 4 h. It is noteworthy that at a low temperature some of the key enzymes such as calpains, cathepsins, and collagenase play an important role to the degradation of the myofibrillar components and may contribute to reducing actomyosin toughness. However, the data on these occasions were not presented in this study. Further investigations of cooking at combined temperatures (2T2T) are needed in order to elucidate possible mechanism in the tenderization process.

We expect by increasing the temperature with the prolonged cooking of sous vide treated beef could increase soluble collagen but instead, it shows lower CS values at 70°C. Similarly, our previous finding in the application of sous vide treatment on bovine semitendinosus muscles at 65°C for 3 h and at 45°C–65°C for 6 h had lower soluble collagen than non-sous vide meat cooked at 75°C for 30 min (Ismail et al., 2019). From those findings, one can conclude that prolonged cooking time in sous vide could reduce soluble collagen by the CL and this observation also has supported by Weston et al. (2002). However, this such result has not shown in the goat meat.

The diagram comparing the principal component 1 (PCA1) versus the principal component 2 (PCA2) represents the total variance in SF, CS, and CL of beef (Fig. 3A) and goat meat (Fig. 3B), thus revealing the differences of conditions and correlation within the samples through the heat treatment used. In beef (Fig. 3A), the plot of the PCA1 scored 96.42% of the variation, encompassing the results of SF and CL with the CL having the highest influence by the temperature. The PCA2 accumulated 3.03% of data variation being weakly correlated to CS. The diagram indicated that, CL had significant influence on SF values ( $r=0.87$ ) and no relationship on CS values ( $r=0.11$ ) in beef. Meanwhile, in goat meat (Fig. 3B), the PCA1 scored 93.89% of variation towards the CL, while PCA2 was representing 3.27% the variation of SF and CS. In contrast to beef, CL in goat meat strongly affected both SF values ( $r=0.53$ ) and CS values ( $r=0.61$ ). Interestingly, both samples of beef and goat meat treated with 2T2T (N45-60) accumulated away from the SF line at the lower left score plot representing lower toughness values.

## Conclusion

The present study reveals that 2T2T sous vide treatments represent comparable values to 1T1T sous vide treatments. Under the condition of this study, it seems that double combination of temperatures-times either at 45°C–60°C, 45°C–65°C, or 45°C–70°C of cooking beef and goat meat leads to different meat features. Notably, the combination at 45°C–60°C produced dramatic lower toughness values of semitendinosus muscles from cattle and goat. While the former treatments at 45°C–65°C and 45°C–70°C also represent good water-holding capacity, color features and lower SF values of beef and goat meat as compared to common sous vide 1T1T treatment. However, results revealed that soluble collagen had less effect on the SF values of beef and goat meat.



**Fig. 3.** Diagram of principal components analysis (PCA) of beef (A) and goat meat (B) on the shear force (SF), collagen solubility (CS), and cooking loss (CL) variables.

## Conflict of Interest

The authors declare no potential conflict of interest.

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## Author Contributions

Conceptualization: Ismail I, Joo ST. Data curation: Ismail I. Formal analysis: Ismail I, Hwang YH. Methodology: Ismail I.

Software: Ismail I. Validation: Joo ST. Investigation: Ismail I, Hwang YH. Writing - original draft: Ismail I. Writing - review & editing: Ismail I, Hwang YH, Joo ST.

## Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

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