# Sous-vided restructured goat meat: Changes in meat qualities during refrigerated storage

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**Abstract** The results showed that all microbial counts of sous-vide sample were significantly increased during storage. The aerobic and anaerobic mesophilic bacteria were higher than 5.70 log cfu/g for 28 days which their counts were below limited microbiological quality of cooked food in Food and Container Standard No. 3, Thailand. *Brochothrix thermosphacta* and pathogen counts as *Staphylococcus aureus*, *Bacillus cereus* and *Clostridium perfringens* were below 1 log cfu/g. Additionally, *Salmonella* spp., *Listeria* spp., *Listeria monocytogenes* were not detected during storage. For physicochemical quality, pH value of sous-vide sample decreased during storage which due to increased lactic acid bacteria counts. Purge loss had significantly increased ($P<0.05$) throughout the storage. CIE L* had significantly increased ($P<0.05$), whereas CIE a* and CIE b* had significantly decreased ($P<0.05$) with increasing storage time. For texture profile analysis, hardness, gumminess, and chewiness had significantly increased ($P<0.05$) as storage time was increased. After grilling, there were significantly increased for grilling loss and significant decreases for CIE a* and CIE b* values ($P<0.05$) throughout storage time. Thus, shelf-life of sous-vided restructured goat meat was 28 days during storage at 4°C

**Keywords:** Shelf-life, Sous-vided meat, Restructured meat, Cold storage

## Introduction

Products are indicated as 'restructured' or 'reformed' which determined to a huge extent by the size of the composition pieces. Meat restructuring connects the assembly of meat slices into an adhesive product which expects to simulate the texture of high-quality muscles (Sorapukdee and Tangwatcharin, 2018). The restructured meat products regularly contain a mixture of meat and non-meat ingredients in which the meat constituent is contamination of microbial, causing the product to be easily putrid and the short shelf-life (Bolger *et al*., 2016). But the pre-cooking as sous-vide technique can decrease pathogenic and spoilage bacteria of pasteurizing temperature (Baldwin. 2011).

Sous-vide cooking technique is determined as the method of heated raw meat packed inside a vacuum pouch in the water baths at a stipulated temperature (Roldán *et al*., 2015). The danger of pasteurized products after cooked does not reduce pathogenic to a safe level (Baldwin. 2011). The safety of sous-vided product depends on the heat and low-temperature storage (New South Wales Government Food Authority. 2015). Coombs *et al*. (2017) reported that the microbial growth, texture analysis and color were factors essential to shelf-life and accordingly to consumer reception of fresh and meat products. The goat meat had higher pH as compared beef and pork but similar to lamb contained an excellent substrate for spoilage bacteria growth.

Although, the sous-vide procedure is used commercially, there has been restricted research work related to sous-vide cooking. It has an effect of quality on meat products and shelf-life (Roldán *et al*., 2015). However, under cooling conditions, the pre-cooked meat product has limited shelf-life, and the improve meat of preservation methods for meat product is necessary (Hong *et al*., 2015). The sous-vide product in the package has a low oxygen container prevents the growth of aerobic spoilage microorganism and increased the time that pre-cooked meat can be preserved (Roldán *et al*., 2015).

New South Wales Government Food Authority (2015) recommended that sous-vided food safety precautions for restaurants meat producers has been required to represent a process adequate to obtain a minimum 6 log cycle reduction of Listeria monocytogenes. The microbiological quality of cooked food in Food and Container Standard No. 3, Thailand (2017) advised that cooked products were required to found below 5.7 log cfu/g for total plate counts,

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below 3 log cfu/g for Clostridium perfringens, below 1 log cfu/g for Staphylococcus aureus, Bacillus cereus and Brochothrix thermosphacta not detected pathogens in 25 g of sample such as Salmonella spp., Listeria spp. and Listeria monocytogenes. Therefore, this study was performed in changes of sous-vided restructured goat meat characteristic during refrigerated storage as determination shelf-life of products during refrigerated storage.

## Materials and methods

### *Preparation of sous-vide product*

The meat was procured mostly from the neck, hind leg and chump of a carcass of male goats (25% Thai native x 25% Anglo-Nubian x 50% Boer, age 15±3 months, weight 40-45 kg) and purchased from the local slaughterhouse in Krabi, Thailand. The goat meat was carryed on ice to the meat laboratory of the Department of Animal Production Technology and Fisheries, King Mongkut's Institute of Technology Ladkrabang for product processing. Then, goat meat was trimmed connective tissue and fat and cut into strips and minced with the meat grinder (Model NB-MM12SS, Sun Food Co., Ltd, Thailand) using 12 mm plates.

The meat samples were mixed with the ingredients of sodium chloride (0.6%), sodium tripolyphosphate (STPP) (0.5%), sodium nitrite (0.3%), water (15.0%), microbial transglutaminase (MTGase) (1.0%) (ACTIVA TG-B powder, Ajinomoto Co., Ltd., Thailand), sodium caseinate (1.0%) using a jar-lift stand mixer (KitchenAid, Professional 600, USA) (Sorapukdee and Tangwatcharin. 2018). The mixture was set into the block, chilled at 4°C for 4 h, frozen at -18°C for 24 h and cut into 15 mm thick further analysis. The samples were packed in vacuum bags and cooked using sous-vide immersion circulator SV100 (Cuisine Craft Co., LTD., Thailand) at core temperature 60°C for 43 min and stored at 4°C for 49 days. The stored samples were sampling every 7 days for analyses.

### *Microbiological analyses*

Twenty-five grams of each sample was relocated into 225 ml of 0.85% sodium chloride (NaCl) and homogenized 1 min using stomacher (Inter science Co., France). Ten-fold dilution preparation of the sample was used 0.85% NaCl. It's definited as colony forming units (log cfu/g) with culturing on media; (1) plate count agar and incubated at 35°C for 24 h and 7°C for 10 days for aerobic and anaerobic bacteria counts (BAM. 2001a), (2) MRS with 0.15% agar and incubated at 35°C for 24 h under anaerobic condition for lactic acid bacteria (LAB) (AOAC. 2006), (3) potato dextrose agar and incubated at 30°C for 24 h for yeast and mold (BAM. 2001b), (4) Baird-Parker agar and incubated at 35°C for 48 h for *Staphylococcus aureus* (BAM. 2001c), (5) Mannitol yolk polymyxin (MYP) agar and incubated at 30°C for 24 h for *Bacillus cereus* (BAM. 2007), (6) Tryptone sulphite neomycin agar and incubated at 35°C for 24 h for *Clostridium perfringens* (BAM. 2001d), (7) Streptomycin-thallous acetate-actidione (STAA) plates and incubated at 25 °C for 48 h for *Brochothrix thermosphacta* (Coombs *et al.* 2017). Coliforms and *Escherichia coli* were enriched by the MPN multiple tube method according to BAM (2002); *Salmonella* spp. was enriched according to the method of to ISO-6579 (2002); *Listeria* spp. and *Listeria monocytogenes* were enriched using the method of BAM (2017).

### *Physical-chemical analyses*

The sous-vided samples before and after storage and grilled sous-vided samples after storage were weighed. The weight of samples was calculated the purge loss (%) and grilling loss (%).

The pH of sous-vide and grilled sous-vide samples were directly measured at three different locations using a standard pH meter (Mettler Toledo 320, Mettler Toledo, Greifensee, Switzerland).

The color was measured on the cut surface of samples after sous-vide and grilling. The CIE L*, CIE L a*, CIE L b* value was determined using by the color meter (Hunterlab Mini Scan EZ LAV, Hunter Associates Laboratory, Inc, USA). Hue angle (hº), chroma (C*) and the ratio was calculated by

$C^* = \sqrt{b^{*2} + a^{*2}}$ , $h^\circ = \tan^{-1}(\frac{b^*}{a^*})$

The sous-vide and grilled sous-vide samples were subjected to texture profile analysis using the texture analyzer (Warner-Bratzler, Instron Model 1011, Instron company, Thailand). Texture profile analysis was operated using middle cores of eight piece of each sample (1.5×1.5×1.5 cm). The texture profile analysis and textural parameter measurement was done at room temperature with the following testing conditions; crosshead speed 60 mm/min, 500 N load cell and compression twice to 40% of their original height. The Bluechill 2 software was used to collect and process the data. The following parameters were determined as hardness (N); chewiness (N); gumminess (N); cohesiveness (ratio) and springiness (ratio) (Sorapukdee and Tangwatcharin. 2018).

### *Statistical analysis*

Data were shown as mean and standard deviations. Significant effects (P<0.05) were performed by one-way ANOVA and mean comparison were compared by the Duncan's multiple range test. Data were analysed using SPSS (v.17. IBM SPSS Inc.).

## Results

The microbial quality of sous-vided restructured goat meat stored at 4°C for 49 days was presented in Table 1. Aerobic mesophilic and psychrotrophilic bacteria counts in sous-vided sample were significantly increased (P<0.05) throughout storage time, ranging from 3.06 to 7.33 log cfu/g of aerobic mesophilic counts and 3.08 to 8.07 log cfu/g of aerobic psychrotrophile counts. The result of aerobic and anaerobic mesophilic bacteria was higher than 5.7 log cfu/g after storage 35 days. The aerobic and anaerobic psychrotrophilic bacteria counts were significantly (P<0.05) as increased storage time and their counts were higher than 5.7 log cfu/g after storage 21 days. In this study was found of spore aerobic and anaerobic mesophilic bacteria counts 1.72 and 1.85 log cfu/g in the sample before storage. However, their counts were below 1 log cfu/g throughout storage at 4°C. LAB counts increased gradually reaching up 2.24 to 8.29 log cfu/g during storage. The molds count was below 1 log cfu/g throughout storage time whereas yeast count recovered and after stored for 28 days. Coliforms could grow after stored for 7 days, ranging from 29 to than 1100 MPN/g. However, *E. coli* was lower than 3 MPN/g throughout storage. The samples were found *S. aureus, B. cereus, C. perfringens and B. thermosphacta* below 1 log cfu/g enough out storage time. *Listeria* spp., *L. monocytogenes* and *Salmonella* spp. was not detected in fresh meat and products and cooked product during the refrigerated storage.

The results of the purge loss (%), pH and color assessment of the sous-vided and grilled sous-vided sample stored at 4°C for 49 days were displayed in Table 2. For sous-vided samples, the purge loss had significantly increased throughout storage time (P<0.05). Storage time had significant effect (P<0.05) on the pH values of the sample. CIE L* has a significant increase (P<0.05) in the storage period. CIE a*, CIE b* and C* had significantly decreased during the storage (P<0.05). Storage time had no significant effect (P<0.05) on hº of the sample. For TPA, the values (hardness, gumminess, and chewiness) had significant increases (P<0.05) during storage time (Figure 1A). The springiness and cohesiveness were not significantly changed during storage time (not show data).

After grilling, the grilling loss had significant increases throughout storage time (P<0.05). CIE L* had a significant increase (P<0.05) in the storage period. CIE a*, CIE b*, C* and hº had significantly decreased during the storage (P<0.05). Hardness, gumminess, and chewiness were significant increases (P<0.05) during storage time (Figure 1B). The springiness and cohesiveness were not changed during storage time (data not shown).

## Discussion

Refrigerated storage affected the microbiological quality and physical-chemical qualities of sous-vided restructured goat meat product in this study. The sous-vide process at 60°C 43 min was good enough for a pasteurized meat due to good microbial quality of the sous-vided sample which was below limited of the microbiological quality of cooked food in Food and Container Standard No. 3, Thailand (Bureau of Quality and Safety of Food. 2017). After refrigerated storage, the sous-vided sample was found the aerobic mesophilic bacteria were below 5.7 log cfu/g of

shelf life in 28 days. Similar to study of Akoğlu *et al.* (2018), the total plate counts of sous-vided turkey cutlet sous-vided at 65°C for 40 min were less than 5.7 log cfu/g until stored at 4°C for 35 days. In this study, LAB counts increased with storage time in anaerobic environments which associated with the spoilage of sous-vided products vacuum packed during storage time (Hong *et al*., 2015).

The storage at 4°C had a negative effect of purge loss value of sous-vided sample as increased storage time ($P<0.05$). Hong *et al.* (2015), Coombs *et al.* (2017) and Otremba *et al.* (1999) reported that purge loss values of lamb meat, chicken breast sous-vide and ostrich meat were significantly increased during storage.

The present study, storage time had no significant effect ($P<0.05$) storage. The present study, storage time had significant effect ($P<0.05$) on pH values, which may be attributed to lactic acid production of LAB counts an increase in anaerobic environments, results in pH values decrease during storage (Hong *et al.*, 2015). The CIE L* was significantly increased ($P<0.05$) in storage period, due to a higher denaturation and aggregation of sarcoplasmic and myofibrillar proteins as increased storage time (Roldán *et al.*, 2015). The increase of CIE a* depended the less myoglobin degradation and mildest cooking temperature, which CIE a* was very stable during the whole storage time (Hong *et al.*, 2015, Roldán *et al.*, 2015). According to this study, CIE a* values of sous-vided and grilled sous-vided samples were found decreased during the storage. Hardness, gumminess, and chewiness were significantly increased ($P<0.05$) during storage time, which agreed with the results of Wattanachant *et al.* (2008). The sous-vided sample had to the strongest cooking with consistently higher values of TPA during storage.

**Table 1.** Microbial counts of raw meat and sous-vided restructured goat meat[/1] during storage at 4ºC for 49 days.

| Microbial | Raw meat | Day of storage at 4ºC[/2] | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 7 | 14 | 21 | 28 | 35 | 42 | 49 |
| Aerobe (log cfu/g) | | | | | | | | | |
| Mesophilic bacteria | 4.22 | 3.06$^{g}$ | 4.06$^{f}$ | 4.66$^{e}$ | 4.98$^{d}$ | 5.07$^{d}$ | 5.73$^{c}$ | 6.97$^{b}$ | 7.33$^{a}$ |
| Spore Mesophilic bacteria | 2.85 | 1.72 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Psychrotrophic bacteria | 3.42 | 3.08$^{g}$ | 4.62$^{f}$ | 5.49$^{e}$ | 6.26$^{d}$ | 6.53$^{c}$ | 7.54$^{b}$ | 7.83$^{a}$ | 8.07$^{a}$ |
| Anaerobe (log cfu/g) | | | | | | | | | |
| Mesophilic bacteria | 4.11 | 3.03$^{g}$ | 4.70$^{f}$ | 4.94$^{ef}$ | 5.32$^{de}$ | 5.49$^{cd}$ | 5.84$^{bc}$ | 6.08$^{b}$ | 6.63$^{a}$ |
| Spore Mesophilic bacteria | 3.96 | 1.85 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Psychrotrophic bacteria | 2.79 | 2.54$^{e}$ | 4.78$^{d}$ | 5.56$^{c}$ | 6.44$^{b}$ | 6.56$^{b}$ | 6.69$^{b}$ | 7.29$^{a}$ | 7.57$^{a}$ |
| Lactic acid bacteria (log cfu/g) | 2.37 | 2.24$^{f}$ | 3.71$^{e}$ | 4.39$^{d}$ | 4.96$^{c}$ | 6.55$^{b}$ | 6.68$^{b}$ | 8.24$^{a}$ | 8.29$^{a}$ |
| Yeast and mold (log cfu/g) | <1 | <1 | <1 | <1 | <1 | 0.79 | 0.87 | <1 | 1.19 |
| *Staphylococcus aureus* (log cfu/g) | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| *Bacillus cereus* (log cfu/g) | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| *Clostridium perfringens* (log cfu/g) | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| *Brochothrix thermosphacta* (log cfu/g) | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 | <1 |
| Coliforms (MPN/g) | 240 | <3 | 29 | 38 | 43 | 64 | 75 | 240 | >1100 |
| *Escherichia coli* (MPN/g) | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 | <3 |
| *Listeria* spp. | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| *Listeria monocytogenes* | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| *Salmonella* spp. | ND | ND | ND | ND | ND | ND | ND | ND | ND |

[1/] The microbiological quality of cooked food in Food and Container Standard No. 3, Thailand (2017) recommend; aerobic mesophile bacteria < 5.7 log cfu/g, *B. cereus* and *S. aureus* < 2 log cfu/g, *C. perfringens* <3log cfu/g, *B. thermosphacta*, *Listeria* spp., *L. monocytogenes* and *Salmonella* spp. not detected in 25 g.

[2/ a-f]; values with the same letter within row were significant different for sous-vided samples during storage (P<0.05). ND; not detected.

**Table 2.** Physical characteristics of sous-vided and grilled sous-vided restructured goat meat during storage at 4 ºC for 49 days.

| Parameter | Day of storage at 4ºC[1,2] | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 0 | 7 | 14 | 21 | 28 | 35 | 42 | 49 |
| Sous-vided samples | | | | | | | | |
| Purge loss (%) | 2.61±0.02$^{f}$ | 2.85±0.16$^{ef}$ | 3.83±0.32$^{de}$ | 4.45±0.07$^{cd}$ | 4.94±0.70$^{bcd}$ | 5.46±0.90$^{abc}$ | 5.68±0.09$^{ab}$ | 6.42±0.56$^{a}$ |
| pH | 6.22±0.01$^{ab}$ | 6.25±0.04$^{ab}$ | 6.23±0.04$^{abc}$ | 6.29±0.01$^{a}$ | 5.99±0.16$^{e}$ | 6.02±0.04$^{cde}$ | 6.00±0.09$^{e}$ | 6.12±0.15$^{bcd}$ |
| CIE L* | 37.01±0.33$^{c}$ | 37.97±1.23$^{c}$ | 38.25±1.57$^{c}$ | 38.82±1.94$^{c}$ | 39.68±3.40$^{bc}$ | 39.54±2.90$^{bc}$ | 42.18±1.02$^{ab}$ | 44.74±1.26$^{a}$ |
| CIE a* | 10.68±0.81$^{a}$ | 10.03±1.56$^{a}$ | 9.93±2.02$^{a}$ | 9.26±2.84$^{a}$ | 9.07±0.47$^{ab}$ | 8.57±0.36$^{b}$ | 8.23±1.68$^{b}$ | 6.69±0.39$^{b}$ |
| CIE b* | 13.59±1.08$^{a}$ | 13.03±0.51$^{ab}$ | 13.01±0.19$^{ab}$ | 12.04±1.14$^{b}$ | 11.89±1.27$^{b}$ | 11.79±0.58$^{bc}$ | 11.58±1.19$^{bc}$ | 10.38±1.02$^{c}$ |
| Chroma (C*) | 17.29±1.12$^{a}$ | 16.47±1.09$^{ab}$ | 16.43±1.34$^{ab}$ | 15.40±1.27$^{bc}$ | 14.97±1.04$^{bc}$ | 14.57±0.68$^{c}$ | 14.23±1.74$^{c}$ | 12.36±0.79$^{d}$ |
| Hue angle (hº) | 51.80±2.43 | 52.56±3.34 | 52.99±1.15 | 53.00±1.04 | 52.50±3.16 | 53.99±0.29 | 54.89±1.53 | 57.09±1.79 |
| Grilled Sous-vided samples | | | | | | | | |
| Grilling loss (%) | 8.91±0.22$^{d}$ | 8.39±0.50$^{d}$ | 8.97±0.31$^{d}$ | 10.47±0.17$^{c}$ | 10.95±1.06$^{c}$ | 12.83±0.22$^{b}$ | 12.89±0.98$^{b}$ | 14.47±0.10$^{a}$ |
| pH | 6.22±0.01 | 6.24±0.04 | 6.21±0.04 | 6.24±0.01 | 6.02±0.03 | 6.01±0.04 | 6.01±0.20 | 6.11±0.10 |
| CIE L* | 30.27±0.37$^{d}$ | 30.91±0.73$^{d}$ | 31.79±0.91$^{cd}$ | 32.91±1.93$^{bcd}$ | 35.49±2.33$^{abc}$ | 35.62±0.54$^{abc}$ | 36.08±0.71$^{ab}$ | 38.69±0.47$^{a}$ |
| CIE a* | 20.20±0.79$^{a}$ | 17.05±0.31$^{b}$ | 15.82±0.67$^{bc}$ | 14.90±0.06$^{bc}$ | 14.36±1.39$^{bcd}$ | 13.78±0.21$^{cd}$ | 12.13±0.10$^{de}$ | 10.88±0.88$^{e}$ |
| CIE b* | 23.05±0.97$^{a}$ | 18.69±0.62$^{b}$ | 15.34±0.79$^{c}$ | 15.09±1.91$^{c}$ | 14.13±0.49$^{c}$ | 13.56±0.04$^{c}$ | 9.97±0.58$^{d}$ | 9.03±0.86$^{d}$ |
| Chroma (C*) | 30.70±0.66$^{a}$ | 25.32±0.70$^{b}$ | 22.05±0.67$^{bc}$ | 21.23±0.56$^{c}$ | 20.16±1.17$^{c}$ | 19.38±1.43$^{c}$ | 15.75±1.67$^{d}$ | 14.16±0.84$^{d}$ |
| Hue angle (hº) | 48.86±0.56$^{a}$ | 47.47±1.48$^{ab}$ | 44.11±0.04$^{b}$ | 45.42±1.19$^{ab}$ | 44.63±1.52$^{ab}$ | 44.27±1.36$^{b}$ | 39.80±0.06$^{c}$ | 39.28±0.45$^{c}$ |

[1/] Each value was expressed as mean± standard deviation.

[2/] $^{a-f}$; values with the same small letter within row are significantly different (P<0.05)

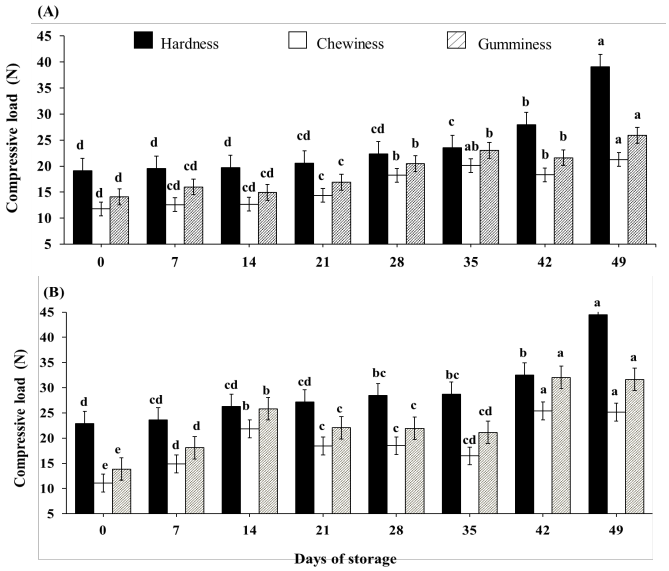


**Figure 1.** Hardness, gumminess, chewiness values of sous-vided (A) and grilled sous-vided (B) restructured goat meat stored at 4ºC for 49 days. (a-e) values with the same letter within the same parameter were significant different (P<0.05).

After grilling, the grilling loss increased during storage (P<0.05) which according to studies of Jinap *et al.* (2015). Hardness, gumminess, and chewiness were significantly increased (P<0.05). Similar results have been reported by Bainy *et al.* (2015) that burgers cooked up to higher internal temperatures around 80°C presented lower texture values.

This study showed that storage time had the negative effect on microbiological and physical qualities of sous-vided sample. Moreover, the shelf-life of the sous-vided sample was 28 days during storage at 4°C.

## Acknowledgments

The authors would like to thank research and researcher for Research and Researchers for Industry (RRi), Thailand Research Fund (TRF) for the financial support (grand number MSD61I0036).

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