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# Comparison of the single-step and double-step sous-vide treatment effect on the quality attributes of chicken breast • A novel approach to sous-vide

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## CONFERENCE FULL PAPER

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**ABSTRACT**

Sous-vide treatment is a modern minimal processing cooking technique that uses a single-step temperature of 55–70 °C and longer time. The quality attributes of meat might be improved by including cooking steps at below 50 °C temperatures in the sous-vide treatment. The aim of this study was to investigate the effects of the double-step sous-vide treatments on the quality attributes of the chicken breast and comparing with the traditional single-step sous-vide treatments. The single-step sous-vide treatments were performed at 60 °C. In the double-step sous-vide treatments the first step temperature was 45 °C and the end temperature was 60 °C. Double-step sous-vide treated chicken breasts obtained higher tenderness, moisture content and lower weight loss compared to the single-step sous-vide treated chicken breasts. Double-step sous-vide treatment provided an attractive cooking method to produce high quality chicken breast, however, challenge tests for specific pathogens would be useful for the assessment of the microbiological quality for different treatment combinations.

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**KEYWORDS**

sous-vide, single-step, double-step, shear force, chicken breast

# INTRODUCTION

The consumption of chicken meat shows an important growth along with the simultaneous increasing of pork consumption over the past two decades. Poultry meat represents a healthy diet for many consumers as it is protein rich, fat poor with high content of PUFA (polyunsaturated fatty acids). These properties are beneficial for the human health particularly for the reduction of the cardiovascular diseases, type 2 diabetes and obesity (Marangoni et al., 2015). Considering these advantages, food scientists have been continuously trying to develop new poultry based ready-to-eat (RTE) meals that meet the consumer preferences and expectations. In this sense, sous-vide method has gained tremendous popularity in the recent years in the catering, RTE producers and households mainly resulting from the consumer demand for minimally processed and convenient food with improved natural quality characteristics and high nutritional value (Zavadlav et al., 2020). Sous-vide processing is considered as a uniform heat treatment of food in heat-stable vacuumed pouches kept in circulation water baths at precisely controlled conditions of time and temperature. The traditional sous-vide method uses a single well controlled temperature in the range of 55–70 °C. The treatment time depends on the type, shape and size of the meat (Baldwin, 2012).

Selection of time and temperature parameters used during sous-vide cooking plays an important role on the meat texture changes due to the denaturation of proteins (Zielbauer et al., 2016). It has been reported that consumers prefer chicken legs over chicken breast, as cooked chicken breast has a tougher texture (Hong et al., 2015). Proteolytic enzymes in meat break down the structure of muscle fiber, which results in higher tenderness (Lawrie and Ledward, 2014). From literature, proteolytic enzymes in meat can remain active up to 50 °C but with higher temperature they start to degrade and inactivate at above 65 °C. The tenderness can be potentially increased by employing the meat's own proteolytic enzymes by fine tuning the sous-vide cooking process by including processing steps below 50 °C. However, careful attention must be taken on this enzyme activation temperature range because it is overlapping the intensive bacterial growth temperature range, which is a possible food safety risk especially in the poultry meat (Yang et al., 2020). According to FSIS (2005), safe poultry product can be produced for the immune-compromised people by a 35 min heat treatment at 60 °C. Based on our knowledge, no studies in the literature can be found on investigating the effect of the double-step sous-vide cooking on quality attributes of chicken breast. Therefore, in our study we compared the effect of the traditional single-step and the double-step sous-vide treatment on the quality attributes of the sous-vide treated chicken breast.

# MATERIALS AND METHODS

## The experimental design of the study

The raw material used for the study was fresh chicken breasts (*musculus pectoralis major*) boneless and free of fat and connective tissues. It was purchased at a local market (Budapest,

Hungary) and was transported without delay to the Department of Animal Products and Preservation Technology, Hungarian University of Agriculture and Life Sciences, Hungary, using an ice filled thermos cool box. Chicken breast meat was cut into uniform pieces (129 ± 4 g weight, 2.0 ± 0.2 cm thickness, 7.0 ± 0.15 cm width and 9.5 ± 0.2 cm length). Chicken breast pieces were randomly selected to form 8 groups consisting of single-step sous-vide treatments (T1, T5) and double-step sous-vide treatment (T2–T4, T6–T8). The first step sous-vide temperature was 45 °C and the second step temperature was 60 °C (Table 1). Each treatment was repeated three times.

The raw material was vacuum packed in the PA/PE pouches and subjected to thermal treatment. Prior to vacuum packaging, a data logger equipped with a needle type thermocouple was placed at the thickest point of one of the chicken breasts samples to monitor the internal temperature during cooking. Sous-vide cooking process was carried out in the thermostatic water bath. After finishing the heat treatment the pouches were cooled back in ice water (1 °C). Samples were kept refrigerated (2 °C) prior to the analysis in the next day. The measured parameters were weight loss, pH, moisture content, Lab color attributes and texture properties.

## Moisture content, cooking yield and weight loss

The AOAC International 950.46 method was used to determine the moisture content by calculating the difference between the weights before and after drying of the samples at 105 °C for 16 h (AOAC, 2005). Cooking yield and weight loss (%) were similarly calculated by using weight data of meat samples before and after cooking.

## pH

The pH was measured with Testo 206 (Hungary) type digital pH analyzer.

## Color

The meat samples color was measured using chroma meter CR-410 type digital colorimeter (Konica Minolta, Inc. Osaka, Japan). The results are reported as $L^*$(lightness), $a^*$ (red–green), and $b^*$ (yellow–blue) determined by the CIE Lab color space. The colorimeter was calibrated on a white standard (CRA43) plate supplied by the manufacturer before each measurement. The

*Table 1.* Processing steps applied in the study

| Treatments | Time at the first step temperature of 45 °C (min) | Time at the end step temperature of 60 °C (min) |
|---|---|---|
| T1 | 0 | 120 |
| T2 | 40 | 80 |
| T3 | 60 | 60 |
| T4 | 80 | 40 |
| T5 | 0 | 180 |
| T6 | 60 | 120 |
| T7 | 90 | 90 |
| T8 | 120 | 60 |

measurement was performed on the (cut) inner surface of meat samples in each case. Five to six repetitions were performed for each meat sample.

### Texture

Texture analysis was performed using an SMS TA.XTplus type device (Stable Micro Systems, United Kingdom). The shear force (SF) was measured using an individual slab shape (15 mm width, 15 mm thickness and 50 mm length) cooked chicken breast. The samples were cut parallel to the muscle fibers using a Warner-Bratzler flat probe. The speed of the head was 2 mm/s before and during measurement. The measured maximum force to shear through the sample, expressed in Newton (N), was used to evaluate the instrumental tenderness of meat. Five cuts were done for each chicken breast sample.

### Statistical analysis

One-Way-ANOVA with post-hoc Tukey test performed with SPSS-23 software (SPSS Inc., IBM Company, USA) was used to detect significant differences between the groups. The differences were considered to be significant at $P \leq 0.05$.

## RESULTS AND DISCUSSION

### Moisture content, cooking yield and weight loss

Moisture content is one of the most important physicochemical attributes in meat along with weight loss. Raw chicken breast showed a moisture content of 74.3% presented in Table 2. As expected, all the double-step sous-vide treated chicken breasts obtained higher moisture content compared to the single-step sous-vide treated chicken breast (T1 and T5) (Fig. 1). The double-step sous-vide treated chicken breast T4 cooked for 80 min at 45 °C and 40 min at 60 °C showed significantly higher moisture content (%) compared to the single-step sous-vide treated chicken breast T1 cooked for 120 min at 60 °C ($P \leq 0.05$). As the cooking time was increased from 40 min to 80 min of the first step temperature of 45 °C it caused an increasing moisture content in the double-step sous-vide treatments (T2–T4). Similar results were obtained in the 3h double-step sous-vide treatments. This can be explained by the fact that lower cooking temperatures result in higher water content in meat because of less release of the muscle fibers sarcoplasmic fluid (Tornberg, 2005).

*Table 2.* Characterization of chicken breast as raw material

| Parameters | Results |
|---|---|
| Moisture content (%) | 74.3 ± 1.24 |
| Weight (g) | 129 ± 4 |
| $L^*$ | 50.63 ± 0.93 |
| $a^*$ | 0.6 ± 0.16 |
| $b^*$ | 3.96 ± 0.1 |
| pH | 5.83 ± 0.04 |

Data are expressed as means ± SD ($n = 3$).

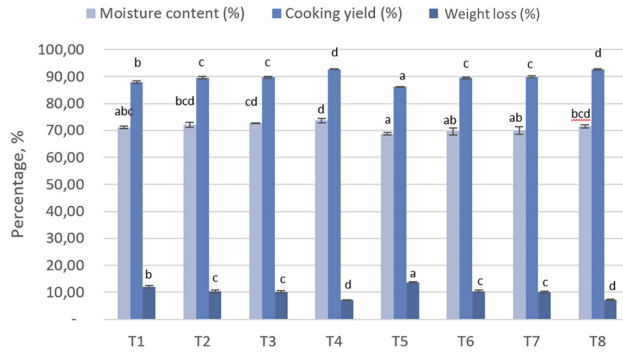


*Fig. 1.* Moisture content, cooking yield and weight loss of the sous-vide chicken breasts cooked at different time-temperature combinations

Weight loss is directly related to the juiciness of the meat, which can have an impact on the perception of the consumer for the final product (Kerr et al., 2005). The 2h and 3h double-step sous-vide treatments which included the early first step temperature of 45 °C, gave lower weight loss compared to the 2h respectively 3h single-step sous-vide treatments at 60 °C (T1 and T5) (Fig. 1). Similar results were observed in the study of Ismail et al. (2019), where the double-step sous-vide cooking treatment reduced the weight loss and improved the water binding capacity of both goat and beef meat. It can be indicated that the lower cooking loss in the case of the double-step sous-vide treatments are due to the effect of the initial cooking temperature (45 °C). At this temperature myofibrillar transverse shrinking can occur leading to larger space between muscle fibers, thus inter-myofibrillar water can be squeezed out easily (Offer et al., 1984). The cooking loss which is released in the vacuum pack at the initial cooking temperature, seems to be reabsorbed by the meat structure before reaching the final temperature of 60 °C. This is an indicator of the protein denaturation process leading to a specific gel formation and improved fibrillar water binding in the meat (Zielbauer et al., 2016). In general, cooking yield was affected strongly by extending the cooking time of the first step low temperature of 45 °C in the analyzed sous-vide treatments. Increasing cooking times at the first step temperature increased the cooking yield from 87.96 to 92.8% in the 2h sous-vide treatments (T1–T4) and from 86.24 to 92.68% at 3h sous-vide treatments (T5–T8). All the double-step sous-vide treatments gave significantly higher cooking yield compared to the single-step sous-vide treatments ($P \leq 0.05$).

T1: 60 °C for 120 min; T2: 45 °C for 40 min and 60 °C for 80 min; T3: 45 °C for 60 min and 60 °C for 60 min; T4: 45 °C for 80 min and 60 °C for 40 min; T5: 60 °C for 180 min; T6: 45 °C for 60 min and 60 °C for 120 min; T7: 45 °C for 90 min and 60 °C for 90 min; T8: 45 °C for 120 min and 60 °C for 60 min. Data with different letters mean the significant difference ($P \leq 0.05$).

## pH

Quality attributes of sous-vide treated chicken breast are shown in Table 3. Chicken breast processed with single- and double-step sous-vide treatments had higher pH in relation to the raw material (pH = 5.83). The 3h single-step sous-vide treatment (T5) had significantly higher pH compared to the 2h single-step sous-vide treatment (T1) ($P \leq 0.05$). Similar results were

*Table 3.* Characterization of chicken breast as sous-vide treated samples

| Time | 2h | | | | 3h | | | |
|---|---|---|---|---|---|---|---|---|
| Treatments | T1 | T2 | T3 | T4 | T5 | T6 | T7 | T8 |
| Shear force (N) | $25.85^{a}$ | $19.89^{bc}$ | $19.02^{cde}$ | $19.05^{cd}$ | $24.37^{ab}$ | $16.52^{cde}$ | $14.03^{de}$ | $13.61^{e}$ |
| $L^*$ | $79.99^{a}$ | $78.55^{bc}$ | $79.04^{b}$ | $76.78^{d}$ | $80.38^{a}$ | $80.06^{a}$ | $78.83^{bc}$ | $78.07^{c}$ |
| $a^*$ | $1.62^{ab}$ | $2.34^{cd}$ | $2.32^{cd}$ | $2.72^{d}$ | $1.34^{a}$ | $2.01^{bc}$ | $2.53^{d}$ | $2.0^{bc}$ |
| $b^*$ | $9.55^{ab}$ | $9.76^{bc}$ | $11.62^{e}$ | $9.96^{cd}$ | $9.19^{a}$ | $9.23^{a}$ | $10.1^{cd}$ | $10.27^{d}$ |
| pH | $6.00^{a}$ | $6.03^{ab}$ | $6.03^{ab}$ | $6.00^{a}$ | $6.13^{c}$ | $6.08^{bc}$ | $6.04^{ab}$ | $6.01^{ab}$ |

T1: 60 °C for 120 min; T2: 45 °C for 40 min and 60 °C for 80 min; T3: 45 °C for 60 min and 60 °C for 60 min; T4: 45 °C for 80 min and 60 °C for 40 min; T5: 60 °C for 180 min; T6: 45 °C for 60 min and 60 °C for 120 min; T7: 45 °C for 90 min and 60 °C for 90 min; T8: 45 °C for 120 min and 60 °C for 60 min. Data with different letters mean the significant difference ($P \leq 0.05$).

found in other studies where the increasing of cooking time resulted in an increase of the pH of sous-vide chicken (Naveena et al., 2017). Between the double-step sous-vide treatments there were no significant differences observed regarding pH values.

## Texture

Tenderness is one of the most important texture parameters for consumers that can be evaluated objectively based on Warner-Bratzler shear force values. Double-step sous-vide treatments tended to decrease the shear force values (N) for chicken breast with the lower values recorded by double-step treatment T8 (Table 3). The low shear force values for the double-step sous-vide treatments could be explained by desmin degradation in myofibrillar muscle component that is known to be an indicator of the extent of meat tenderization during proteolysis (Zhang et al., 2006). Davey and Gilbert (1976) have found an exponential relation between the proteolytic activity and temperatures up to 40 °C. This may be the reason why the double-step sous-vide method using the temperature of 45 °C showed lower shear force values in the case of chicken breast.

## Color

Color parameters are usually used as indicative features of the quality and attractiveness of the product for consumers. The changes in color parameters in sous-vide treated meat can be caused by myoglobin denaturation, the oxidative state of myoglobin, pH and less by Maillard reactions because of the use of low temperatures in the sous-vide method (Ayub and Ahmad, 2019). With the exception of T6 treatment, lightness ($L^*$) was significantly lower in all of the 2h and 3h double-step sous-vide treatments compared to the 2h and 3h single-step sous-vide treatment (T1 and T5) ($P \leq 0.05$) (Table 3). Similar results were introduced by Ismail et al. (2019) in sous-vide treated cattle and goat cooked at single-step and two-step treatments. In our study chicken breast showed a pale appearance ($L^* > 53$) in both single-step and double-step sous-vide treatments based on the $L^*$ values (Da-Silva Buzanello et al., 2019).

The $a^*$ value was measured in the range of 1.53–2.72. Redness was significantly higher in all of the 2h and 3h double-step sous-vide treatments compared to the 2h and 3h single-step sous-vide treatment (T1 and T5) ($P \leq 0.05$). These results show that the redness was preserved in the 2h and 3h double-step sous-vide treated chicken breast. Treatments preserved better the

myoglobin molecules because the denaturation of myoglobin starts well over the applied treatment temperatures (55 and 65 °C) (Hunt et al., 1999). The $b^*$ value ranged from 9.19 to 11.62. Double-step sous-vide treated chicken breasts showed higher yellowness than those cooked using a single-step sous-vide method (Table 3). This can be explained with the fact that the cooking period of the double-step sous-vide cooked chicken breasts exposed to the second temperature (60 °C) was shorter than that of single-step sous-vide cooked chicken breasts.

## CONCLUSIONS

The present study reveals that cooking conditions significantly affected the physiochemical quality attributes of sous-vide chicken breast. Double-step sous-vide treatments provided an attractive cooking method to produce high quality chicken breast as it reduced shear force values while obtained higher moisture content, redness and lower weight loss of chicken breast as compared to the traditional single-step sous-vide treatment. According to FSIS (2005) it takes 35 min at 60 °C of cooking poultry to be made safe even for the immune-compromised people. The selected time and temperature combination treatments seems to meet the food safety criteria; however, it would be useful to carry out challenge tests of specific pathogens to assess the effectiveness of the treatment combination on microbiological quality.

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