# Quality Improvement of Marinated Pork Stew in Retort Pouch for the Elderly

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## Abstract

Population aging, which affects virtually every country in the world, involves growth in the number and proportion of older people in the population. The aim of this study was to develop a marinated pork stew packed in a retort pouch that provided food properties suitable for the elderly. Pork loin was treated with different alkaline solution marinades including 5% sodium chloride (M-SC), 5% sodium bicarbonate (M-SBC) or 5% sodium tripolyphosphate (M-STPP) and compared with the control (non-marinated pork). The marinated pork increased pH, cooking yield, redness (a* value) and color difference (ΔE*), while decreased cooking loss, lightness (L* value), yellowness (b* value) and enhanced texture properties of pork. M-SBC gave significantly ($p \leq 0.05$) the lowest cooking loss and lightness as well as hardness and shear force value. Therefore, M-SBC was selected to develop marinated pork stew through thermal processing by retort technology to produce convenient food for the elderly. The products after sterilizing could be stored at normal temperature and had longer shelf life. The $F_0$ value of 6.0 was found to be adequate for marinated pork stew. After thermal processing, the L* and b* values of stew color significantly increased ($p \leq 0.05$) whilst the a* value of stew color significantly decreased ($p \leq 0.05$). The texture of the marinated pork improved as indicated by decrease in hardness, cohesiveness, chewiness, and shear force value. Nevertheless, the protein content of marinated pork stew significantly ($p \leq 0.05$) increased after thermal processing. The final marinated pork stew product was evaluated by the elderly folks and accepted with a moderate liking score.

**Keywords:** marination; pork stew; retort pouch; the elderly
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## 1. Introduction

Population aging, an inevitable increase in the number of elderly people resulting from declining fertility and expanding longevity, is taking place around the world. In 2019, the global population aged 65 and over amounted to 703 million. East and Southeast Asia were home to the highest proportion of the world's older population, followed by Europe and North America. The number of elderly people is projected to double to 1.5 billion by 2050 [1].

Aging can be biologically considered to be a morpho-functional involvement, variably affecting major physiological systems [2]. Several physiological changes that occur in the healthy aging process are associated with a declining gustatory function in the elderly such as

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chemosensory perception, oral health, and olfactory function [3]. Decrease in taste perception is possibly caused by an age-related reduction in the number of taste buds on the tongue papillae and a shorter life span of the receptor cells. The loss of threshold sensitivity in the elderly presumably compromises their ability to recognize and appreciate subtle flavors and tastes of foods [4]. Additionally, edentulism is more frequent with advancing age and tooth loss peaks already at around 65 years. The loss of all teeth also reduces masticating efficiency and affects food taste, food preferences, and food consumption patterns. Chewing difficulties induce elderly people to limit their diet to soft foods and to avoid hard textures (such as fresh fruits and vegetables, meat, and even bread) which adversely affects their nutritional status [3, 5]. Thus, there is an urgency to develop and provide easily chewable elderly food products to maintain health and promote the nutrition of the elderly.

Texture is one of the most important aspects of meat quality affecting consumer acceptability, especially in elderly people. Other important aspects required for the acceptance of meat products are appearance or color and taste [6]. Marination is the process in which meat is immersed in different marinade solutions including alkaline or acidic solutions and water-oil emulsions [7]. Acidic solutions cause the structure of meat to loosen, allowing water absorption and producing a tenderer and juicer product but adversely affecting flavor and appearance of meat [8]. The addition of alkaline solution containing salt, phosphate and carbonate are also used to enhance the quality of pork and other meat products [9]. The mechanism responsible for the increased tenderness and juiciness is connected with higher water holding and swelling of myofibrils [10]. Effectiveness of the marination process can be affected by many factors such as type of marinade solution, marination procedure, holding time and temperature [11].

Retort thermal processing involves a combination of high temperature and pressure in a hermetically sealed flexible retort pouch to eliminate all pathogenic and spoilage microorganisms of concern in food products [12]. Overpressure water spray retort has been used for thermal processing with different types of container such as retort pouches, glass bottles, plastic or aluminium containers, etc. With directed steam injection, continuous water spray results in homogeneous heat distribution in the vessel during both sterilizing and cooling. The technical and commercial feasibilities of using retort pouches for thermal processing have been proven by various studies for different meat products like buffalo meat block [13], pork curry [12], Chettinad chicken [14] and Chettinad goat meat curry [15]. Retort pouches offer a number of advantages over metal cans including better storage stability, reduced weight and storage space, ease of opening and preparation, longer shelf life and reduced heat exposure resulting in more quality [16]. Food texture properties suitable for the elderly should be soft, moist and cohesive, while textures that are sticky, adhesive and of fibrous structures should be avoided [17]. Besides measurement by sensory texture evaluations, instrumental methods have been used to determine textural changes. Thus, this research was conducted to develop the marinated pork stew in retort pouch that provided food properties suitable for the elderly.

## 2. Materials and Methods

### 2.1 Preparation of marinated pork

Frozen pork loin (pH=6.09) was purchased from P.S. Food Product Co., Ltd., Thailand and transported to the laboratory under chilled condition (0-2°C). Pork was washed with potable water and cut into small cubes of 1.8 cm size using a sterilized knife. The pork cubes were dipped in marinade solution: 5% sodium chloride (M-SC) (Ajax Finechem Pty Ltd., Australia), 5% sodium bicarbonate (M-SBC) (Continental Food Co., Ltd, Thailand) or 5% sodium tripolyphosphate (M-STPP) (SD BNI (CN) Co., Ltd., China). The mixture was applied in a ratio of meat: marinade solution of 10:1 (w/w). Non-marinade pork was used as a control. The marinade pork and control sample were packed in polyethylene bags and stored under 0-2°C for 15 h. Then, all pork cubes were precooked with steaming to reach minimum internal temperature of about 63°C [18] which was the USDA's safe temperature recommendation for pork.

## 2.2 Preparation of stew mix

A selected stew formula from three recipes was prepared as described by Spitler and Yoakam [19], with slight modification. The selected formula received the highest significant ($p \leq 0.05$) 9-hedonic liking scores with greater than 7.0 (likely moderately) for appearance, flavor, taste, texture and overall liking by the elderly aged over 60 years old (n=50). An average volume of 20 ml of each sample was served at room temperature in a 2 oz plastic cup, covered with a lid and labeled with a 3-digit random code. The ingredients used for preparation of stew were as follows: tomato sauce (42.2%), brown sugar (6.5%), cider vinegar (2.6%), Worcestershire sauce (1.6%), black pepper (0.1%) and water (47.0%). To this mix, predetermined quantities of tomato sauce, brown sugar, cider vinegar, Worcestershire sauce and black pepper were added to boiling water, mixed, and cooked for few min. Stew mix was precooked until the temperature reached around 90°C. All ingredients for the preparation of stew mix were purchased from Siam Makro Holding (Thailand) Limited.

## 2.3 Filling and sealing of retort pouch

Laminated flexible pouch (120x175x35 mm) made of four layers (Royal Meiwa Pax Co., Ltd., Thailand) was used for packing the pork stew, consisting of 12 µm polyethylene terephthalate (outer layer), 15 µm nylon, 9 µm aluminium foil (middle layer), and 80 µm polypropylene (inner cast). About 72±5 g precooked pork cubes were filled into the retort pouches. Each pouch was filled with 48±0.5 g of stew mix, keeping a pack weight of approximately 120±5 g. Controlled handling of filled pouches during and between operations was undertaken to prevent contamination of the seal area. Residual air was removed and the pouches were sealed with a vacuum packaging machine (Multivac A300/42, Germany). Initial temperature of precooked pork was measured to be about 30°C. The pouches were drilled at 30% of the pouch height and product core temperature during processing was monitored using thermocouples inserted into core of precooked pork in five of the pouches using ducts. Two thermocouples were kept in the retort chamber to monitor the chamber temperature. Filled and sealed pouches were placed flat on trays in the retort processing unit. The sealed pouches were subjected to thermal processing for optimizing the $F_0$ value at process temperature.

## 2.4 Overpressure water spray retort

A pilot-scale overpressure retorting unit (SR Advance Technology Co., Ltd, Thailand) used for thermal processing consisted of retort, boiler, air compressor, centrifugal pump and Programmable Logical Control (PLC). The unit used in this study was similar to commercial-scale equipment which produced a high level of accuracy and reproducibility. For the thermal processing, the temperature of retort chamber was set at 116.0°C and an overpressure of 1.8 bar was maintained throughout the process cycle. After the pouches were processed to the required $F_0$ value, they were rapidly cooled to 50±10°C by spraying water under pressure. The heat penetration characteristics were determined using a general method [20]. Total process time was determined by adding process time and the effective heating period during the come-up time i.e. 42% of the come-up time (CUT). Based on the time-temperature data recorded using the PLC, CUT, process time and cooling time were determined. The lethal rate (L) was also calculated based on equation (1) and the $F_0$ value was able to be obtained from the area under the curve between lethal rate and time based on equation (2). The pouches were then dried, labelled and stored until further analysis.

$$L = 10^{(T-Tr)/Z} \qquad (1)$$

Where T is the temperature in degree Celsius (°C), at which the lethal rate is calculated and $T_r$ of 121.1°C is the reference temperature, to which the equivalent lethal effect is compared. The z-value of 10°C is the value frequently used in $F_0$ calculation performed on low acidic foods.

$$(F_0)_i = \frac{(L_{i-1} + L_i)}{2} \times \Delta T \qquad (2)$$

Where $L_{i-1}$ is the cumulative lethal rate, $L_i$ is the current lethal rate and ΔT is the interval time.

## 2.5 Determination of pH and water activity ($a_w$)

The pH value of samples was determined according to the method of AOAC [21] using a pH meter (Mettler Toledo, S220K, Switzerland) calibrated with standard buffer solutions of pH 4.0 and 7.0. Water activity ($a_w$) of samples was measured at 25°C according to the method of AOAC [21] using a water activity instrument (AquaLab, 4TE, USA).

## 2.6 Weight changes during pre-cooking

Weights of pork cubes were recorded before immersion ($w_1$), before pre-cooking ($w_2$) and after pre-cooking ($w_3$). The following calculations were made:

$$\text{Cooking loss (\%CL)} = [(w_2 - w_3)/w_2] \times 100 \qquad (3)$$

$$\text{Cooking yield (\%CY)} = (w_3/w_1) \times 100 \qquad (4)$$

## 2.7 Color measurement

The color of flat surface in the center of each sample and stew mix was determined using a colorimeter (Hunter Lab, Colorflex-45-2, USA). The CIE color values of each sample were reported as L* (0=black, 100=white), a* (-a*=greenness, +a*=redness) and b* (-b*=blueness, +b*=yellowness). Moreover, the reported L*, a* and b* values were calculated as color difference (ΔE*) via the following formula:

$$\Delta E^* = \sqrt{(L^* - L_0^*)^2 + (a^* - a_0^*)^2 + (b^* - b_0^*)^2} \qquad (5)$$

where L*, a* and b* are values for the samples. $L_0^*$, $a_0^*$ and $b_0^*$ are values for the control.

## 2.8 Texture analysis

Texture profile analysis (TPA) was performed with a texture analyzer (TA-XT Plus, Stable Micro Systems, UK) using the method of Majumdar *et al.* [22]. The samples were allowed to equilibrate to room temperature. A load cell of 50 kg and a cylindrical probe of 50 mm diameter were used. The texture measurement included two consecutive 40% compressions of the sample at a crosshead speed of 12 mm/min. From the resulting force-time curve, the values of various texture parameters including hardness (N), cohesiveness, springiness index and chewiness (N) were recorded.

The maximum force required to cut the sample was determined as shear force value with a texture analyzer (TA-XT Plus, Stable Micro Systems, UK) using the method of Majumdar *et al.* [22]. The load cell used for shear force value was of 50 kg capacities. Each cube of cooked pork was placed individually under a Warner-Bratzler shear blade and cut at the center of the sample. The crosshead speed of the machine was maintained at 5 mm/sec. From the force-deformation curves, the maximum shear force was determined, which was indicative of toughness and expressed as N/mm.sec.

## 2.9 Proximate composition

Proximate composition of the samples was undertaken based on AOAC [21]. Moisture content was obtained using air-oven dried method (105°C). Ash was determined by incineration in a muffle furnace at 550°C. Protein content was determined by the Kjeldahl technique. The composition of fat in the samples was determined by the solvent extraction method. Carbohydrate was determined by subtracting from 100, the sum of moisture, ash, protein and fat percentages. Total energy was calculated as: Energy = (protein x 4) + (fat x 9) + (carbohydrate x 4).

## 2.10 Sensory evaluation

Panelists were invited to describe the test detail and to verify their capability to understand the test method, as well as their interest and willingness to participate in the test. This study was approved by the ethics committee of Ramkhamhaeng University (RU-HS-RESC/xd-0122/62). Fifty panelists (12 males and 38 females) aged over 60 years old participated through personal communication screening. They were recruited from the life quality development center for the elderly in Nonthaburi city municipality. The 3 samples of marinated pork and control were precooked with steaming to reach minimum internal temperature of about 63°C and served at room temperature. Samples were provided in two pieces of pork and presented in a 2 oz disposable cup, labeled with 3-digit random numbers. Presentation order was randomized to avoid any serving order bias for all panelists. The panelists were instructed to sip water between samples to cleanse the palate. Then, they were asked to evaluate liking scores using a 9-point hedonic scale (1=dislike extremely, 5=neither like nor dislike and 9=like extremely) for the attributes of appearance, flavor, tenderness, juiciness and overall likings of the samples whilst using a just about right (JAR) scale (1=not enough, 2=just about right and 3=too much) for the attributes of tenderness and juiciness [23].

For consumer acceptance test, one hundred elderly (30 males and 70 females) participated in the test through personal communication screening. The central location test (CLT) for consumer acceptance was performed. Participants were recruited from the life quality development center for the elderly in Nonthaburi city municipality. The marinated pork stew in retort pouch were provided in two pieces of pork with 20 ml of stew mix and presented in a 2 oz disposable cup, labeled with 3-digit random numbers. Then, they were asked to evaluate liking scores using a 9-point hedonic scale for the attributes of appearance, flavor, taste, tenderness, juiciness and overall liking scores as well as acceptance and buying decision.

### 2.11 Microbiological analysis

According to the Thai Food and Drug Administration (FDA), the samples were processed at the required $F_0$ values followed the condition stated in the Notification of the Ministry of Public Health No.355 B.E.2556 (2013) Re: Food in a Hermetically Sealed Container for commercial sterilization to ensure food safety, which were as follows: total plate count (TPC), yeast and mold, coliforms, *Staphylococcus aureus, Salmonella* spp. [24], microbial growth at 35°C and 55°C and *Clostridium botulinum* [25].

### 2.12 Statistical analysis

The experiment was conducted according to a completely randomized design (CRD) with three replications. For each analysis, triplicate measurements were performed. Statistical analysis for sensory evaluation followed a randomized complete block design (RCBD) with subjects as blocks. Data were subjected to analysis of variances (ANOVA) using SPSS software (version 18.0; SPSS (Thailand) Co., Ltd., Bangkok, Thailand). Duncan's multiple range tests were performed to determine significant differences among treatments at 95% confidence level ($p \leq 0.05$). Pearson's correlation analysis was used to investigate the relationship between instrumental measurements. Comparison of physical and chemical measurement between before and after thermal processing were tested by paired t-test.

## 3. Results and Discussion

### 3.1 Effect of marination on pork quality

The qualities of marinated pork and control after pre-cooking are shown in Table 1. The pH values of pork were increased by the alkaline solutions after marination. M-SBC gave ($p \leq 0.05$) the significantly highest pH, whereas M-SC was not significant different ($p > 0.05$) compared to the control. The results for pH of pre-cooked pork followed similar trends as for pH of marinated pork. Among all marinated pork, M-SBC had significantly ($p \leq 0.05$) the lowest cooking loss and the highest cooking yield. Moreover, the results also showed that pH of marinated and pre-cooked pork were negatively correlated with cooking loss ($R^2 = -0.95$ and $R^2 = -0.89$, respectively) and were positively correlated with cooking yield ($R^2 = 0.86$ and $R^2 = 0.73$, respectively) (Table 2). Marination reduced cooking loss and increased cooking yield, presumably due to improved water holding capacity at high pH levels [10].

Pre-cooked pork color, shown in Table 1, revealed significant ($p \leq 0.05$) decrease in L* and b* values of all marinated pork in comparison with the control. M-SBC showed significantly ($p \leq 0.05$) higher a* value than the values of others, leading to a higher ΔE* value with visible color change. Most food additives used in meat products caused color changes by altering the pH and chemical state of myoglobin [9]. It was found that meat with pH greater than 5.7, marinated with sodium chloride, bicarbonate and tripolyphosphate showed significantly lower L* values. Additionally, pH of marinated pork was negatively correlated with L* value ($R^2 = -0.74$) and was positively correlated with a* ($R^2 = 0.64$) and ΔE* ($R^2 = 0.73$) values, indicating that the higher pH decreased the lightness and increased the redness of pork (Table 2).

The texture profiles of marinated pork and control after pre-cooking are also shown in Table 1. All marinated pork had lower hardness, springiness index, cohesiveness, chewiness and shear force values than those of the control. M-SBC had significantly ($p \leq 0.05$) the lowest hardness

**Table 1.** Qualities of marinated pork and control after pre-cooking

| Qualities | Control* | M-SC* | M-SBC* | M-STPP* |
|---|---|---|---|---|
| **pH (marinated pork)** | 6.09 ± 0.12$^c$ | 6.17 ± 0.08$^c$ | 6.61 ± 0.04$^a$ | 6.39 ± 0.03$^b$ |
| **pH (pre-cooked pork)** | 6.52 ± 0.03$^c$ | 6.49 ± 0.02$^c$ | 7.13 ± 0.04$^a$ | 6.62 ± 0.05$^b$ |
| **%Cooking loss (%CL)** | 22.56 ± 0.13$^a$ | 22.54 ± 0.35$^a$ | 15.97 ± 0.19$^c$ | 18.39 ± 0.24$^b$ |
| **%Cooking yield (%CY)** | 73.56 ± 0.43$^d$ | 82.38 ± 0.35$^c$ | 89.61 ± 0.58$^a$ | 85.61 ± 0.49$^b$ |
| **Pre-cooked pork color** | | | | |
| - L* | 66.97 ± 0.46$^a$ | 62.96 ± 0.43$^b$ | 61.80 ± 0.27$^c$ | 62.53 ± 0.30$^b$ |
| - a* | 1.28 ± 0.19$^b$ | 1.32 ± 0.24$^b$ | 1.90 ± 0.06$^a$ | 1.27 ± 0.14$^b$ |
| - b* | 11.06 ± 0.05$^a$ | 10.06 ± 0.09$^d$ | 10.50 ± 0.07$^c$ | 10.85 ± 0.13$^b$ |
| - ΔE* | - | 4.14 ± 0.40$^b$ | 5.24 ± 0.27$^a$ | 4.45 ± 0.30$^b$ |
| **Pre-cooked pork texture** | | | | |
| - Hardness (N) | 83.99 ± 2.54$^a$ | 64.28 ± 0.40$^b$ | 45.02 ± 0.64$^d$ | 56.33 ± 1.02$^c$ |
| - Springiness index | 2.94 ± 0.17$^a$ | 2.11 ± 0.33$^b$ | 1.01 ± 0.01$^c$ | 1.42 ± 0.33$^c$ |
| - Cohesiveness | 0.65 ± 0.00$^a$ | 0.64 ± 0.01$^b$ | 0.63 ± 0.00$^c$ | 0.63 ± 0.00$^c$ |
| - Chewiness (N) | 160.84 ± 14.88$^a$ | 86.89 ± 14.90$^b$ | 28.46 ± 0.73$^c$ | 50.52 ± 12.56$^c$ |
| - Shear force (N/mm.s) | 20.28 ± 0.66$^a$ | 17.94 ± 0.40$^b$ | 16.32 ± 0.26$^d$ | 17.16 ± 0.13$^c$ |

*Values within the same row with different superscript letters are significantly different ($p \le 0.05$).
Non-marinated pork serves as a control sample. M-SC, M-SBC and M-STPP are marinated pork treated with sodium chloride, sodium bicarbonate and sodium tripolyphosphate, respectively.

and shear force value, whereas no significant ($p>0.05$) differences in springiness index, cohesiveness and chewiness were found between M-SBC and M-STPP. In addition, negative correlations were observed ($p \le 0.01$) between pH of marinated pork and hardness ($R^2$ = -0.87), springiness index ($R^2$ = -0.88), cohesiveness ($R^2$ = -0.81), chewiness ($R^2$ = -0.83), and shear force ($R^2$ = -0.81) (Table 2). The results indicated that higher pH improved textural characteristics of marinated pork after pre-cooking, making the pork softer. The results of this study were consistent with those conducted by Petracci *et al.* [26] who reported that the mechanism in improving texture of meat by sodium chloride solution might increase the protein solubility and fat emulsification of the meat without the effect of pH. Hence, sodium chloride solution had a lower power to improve the water holding capacity of marinated meat than those of the others. Both sodium bicarbonate and tripolyphosphate solutions were alkaline and could increase the negative charge of protein by increasing the pH away from the isoelectric point of myofibrillar proteins [27]. Kaewthong and Wattanachant [28] reported that the smaller size of $HCO^{3-}$ ions might penetrate into meat muscle and interact with many protein side-chains, resulting in more increased repulsive force among meat proteins, compared to $(P_3O_{10})^{5-}$ ions. Therefore, sodium bicarbonate solution had a better ability to improve water holding capacity than that sodium tripolyphosphate solution. Moreover, sodium bicarbonate solution had a superior capacity to improve the pH of meat compared to that of sodium tripolyphosphate solution, which might be due to its higher buffering capacity [29]. Besides causing change in protein charge, sodium bicarbonate solution also released carbon dioxide during cooking process improving the ability to hold water by physical entrapment of water [30]. In addition, Sheard and Tali [10] showed air-filled pockets around fiber bundles and longitudinal splits of cooked pork loin treated with sodium bicarbonate, which led to dilution of the load-bearing element and reduction of the shear force value.

**Table 2.** Pearson's correlation coefficients of various qualities of pork

| | pH marinated pork | pH pre-cooked | %CL | %CY | L* | a* | b* | ΔE* | Hard ness | Springi-ness index | Cohesive-ness | Chewi-ness | Shear force |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH (marinated pork) | 1 | | | | | | | | | | | | |
| pH (pre-cooked pork) | 0.87** | 1 | | | | | | | | | | | |
| %CL | -0.95** | -0.89** | 1 | | | | | | | | | | |
| %CY | 0.86** | 0.73** | -0.85** | 1 | | | | | | | | | |
| L* | -0.74** | -0.55 | 0.69* | -0.96** | 1 | | | | | | | | |
| a* | 0.64* | 0.85** | -0.69* | 0.60* | -0.47 | 1 | | | | | | | |
| b* | -0.11 | -0.07 | -0.04 | -0.44 | 0.58* | -0.14 | 1 | | | | | | |
| ΔE* | 0.73** | 0.54 | -0.68* | 0.96** | -1.00** | 0.48 | -0.60* | 1 | | | | | |
| Hardness | -0.87** | -0.76** | 0.87** | -1.00** | 0.94** | -0.64* | 0.42 | -0.94** | 1 | | | | |
| Springiness index | -0.88** | -0.74** | 0.88** | -0.95** | 0.89** | -0.65* | 0.26 | -0.89** | 0.96** | 1 | | | |
| Cohesiveness | -0.81** | -0.69* | 0.86** | -0.91** | 0.85** | -0.59* | 0.19 | -0.84** | 0.92** | 0.94** | 1 | | |
| Chewiness | -0.83** | -0.68* | 0.84** | -0.98** | 0.95** | -0.59* | 0.38 | -0.94** | 0.98** | 0.99** | 0.94** | 1 | |
| Shear force | -0.81** | -0.67* | 0.81** | -0.98** | 0.96** | -0.57 | 0.45 | -0.95** | 0.98** | 0.96** | 0.93** | 0.99** | 1 |

*Correlation is significant at p≤0.05. **Correlation is significant at p≤0.01.

### 3.2 Effect of marination on sensory evaluation

Marination improved liking scores of appearance, flavor, tenderness, juiciness and overall in the evaluation done by the elderly compared to those of the control (Table 3). M-SBC had significantly ($p \le 0.05$) the highest liking score of tenderness among all types of marinated pork, whereas liking scores of juiciness among all marinated pork types were not significantly different ($p > 0.05$). However, Santos *et al.* [31] reported that juiciness and tenderness were positively correlated. Juiciness of marinated pork loins could be described by water loss reduction from exudation and cooking process treated with alkaline brines, positively affecting the sensory characteristics [31]. Furthermore, no difference in flavor liking scores were found between M-SBC and the control which were significantly ($p \le 0.05$) lower than those of M-SC and M-STPP. Marinated pork treated with sodium bicarbonate and non-marinated pork provided meaty flavor that was disliked by some elderly. Marinated pork treated with sodium chloride and sodium tripolyphosphate provided salty and soapy flavors, respectively. Similar results were found by Sheard and Tali [10], who observed a salty flavor in samples treated with salt alone or in combination and a slight soapy flavor in samples treated with phosphate. However, they found that there were no off-flavors in samples treated with bicarbonate. This suggested that concentration of marinade solutions should be sufficient to improve tenderness and juiciness without adversely affecting color, flavor and texture. In terms of JAR rating, all marinated pork received more than 70% JAR responses for each attribute, except for juiciness of M-SC as 66% JAR and -30% net score (data not shown). This result indicated that M-SC marinated pork was a little too juicy compared to the others. Therefore, marinated pork treated with sodium bicarbonate was selected to be used in the study of thermal processing in development of marinated pork stew for the elderly because it was effective in the improvement of pork quality.

**Table 3.** Sensory attributes of marinated pork and control after pre-cooking

| Attributes | Control* | M-SC* | M-SBC* | M-STPP* |
|---|---|---|---|---|
| Appearance | $6.22 \pm 1.54^{b}$ | $6.72 \pm 1.34^{a}$ | $6.90 \pm 1.37^{a}$ | $6.78 \pm 1.47^{a}$ |
| Flavor | $6.24 \pm 1.32^{b}$ | $6.70 \pm 1.37^{a}$ | $6.54 \pm 1.42^{ab}$ | $6.72 \pm 1.28^{a}$ |
| Tenderness | $6.06 \pm 1.35^{c}$ | $6.60 \pm 1.18^{b}$ | $7.08 \pm 0.90^{a}$ | $6.72 \pm 1.23^{b}$ |
| Juiciness | $6.02 \pm 1.36^{b}$ | $6.70 \pm 1.23^{a}$ | $7.02 \pm 1.24^{a}$ | $6.74 \pm 1.35^{a}$ |
| Overall liking | $6.06 \pm 1.36^{b}$ | $6.80 \pm 1.14^{a}$ | $7.14 \pm 1.11^{a}$ | $6.88 \pm 1.26^{a}$ |

*Values within the same row with different superscript letters are significantly different ($p \le 0.05$). Non-marinated pork serves as a control sample. M-SC, M-SBC and M-STPP are marinated pork treated with sodium chloride, sodium bicarbonate and sodium tripolyphosphate, respectively.

### 3.3 Effect of thermal processing on physical changes in marinated pork stew

The heat penetration characteristics of marinated pork stew in retort pouch are shown in Figure 1. Experimental study of thermal processing indicated that $F_0$ value of 6.0 was optimum to achieve commercial sterility of retort processed pork stew. The total processing time included 11 min for come-up time (CUT), 42 min for processing time and 39 min for cooling time. The results of microbiological analysis, TPC, yeast and mold, and coliforms were less than 10 cfu/g, 10 cfu/g and 3 MPN/g, respectively. Moreover, there were not detection of microbial growth at 35°C and

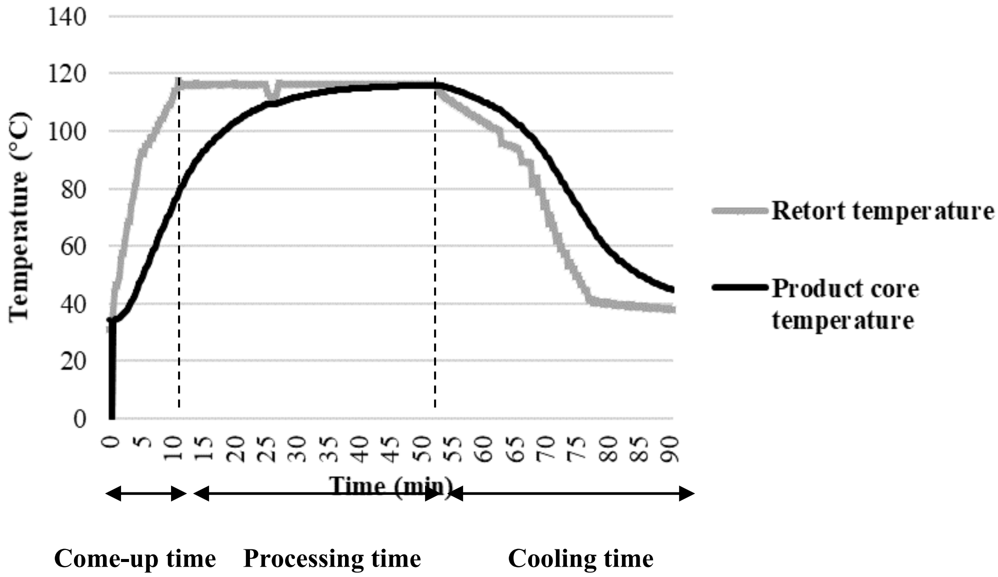


**Figure 1.** Heat penetration characteristics of marinated pork stew in retort pouch

55°C*, Staphylococcus aureus, Salmonella* spp. and *Clostridium botulinum* in marinated pork stew in retort pouch. According to Thai Food and Drug Administration (FDA), the $F_0$ value used to sterilize low acidic foods must take at least 3 min to sufficiently kill *Clostridium botulinum* spores. Thermal processing of meat comes with changes in appearance, smell, taste and texture. Additionally, thermal processing also induced undesirable changes in meat quality, such as the loss of nutritional value caused by lipid oxidation and changes in composition of protein fraction [32].

The data in Table 4 shows physical changes of marinated pork stew in retort pouch after processing. Stew color showed significant ($p \leq 0.05$) increase in L* and b* values, whereas a* value was significant ($p \leq 0.05$) decreased after processing. This indicated higher lightness and yellowness and lower redness of stew color compared to stew color before processing, resulting in visible color difference (ΔE*). The release of moisture content of marinated pork into the stew during retort processing might have contributed to the lighter and yellower stew color.

The textural properties of marinated pork stew before and after processing are also shown in Table 4. The results showed that hardness, cohesiveness, chewiness and shear force value of marinated pork stew in retort pouch significantly decreased ($p \leq 0.05$) after processing. However, there was no significant difference ($p > 0.05$) in the springiness index of marinated pork stew in retort pouch after processing. This indicated that the pork product was softened owing to the effect of moist heat at high temperature. Girish *et al.* [12] also reported decrease in cohesiveness, chewiness, firmness and work of shear as well as increase in springiness index after retort processing of ready-to-eat pork curry product.

### 3.4 Effect of thermal processing on chemical changes in marinated pork stew

The proximate composition of marinated pork stew is shown in Table 5. Protein and fat contents increased after retort processing, which may be linked to a reduction in carbohydrate and ash

**Table 4.** Physical changes of marinated pork stew in retort pouch

| Physical changes | Before processing* | After processing* |
|---|---|---|
| **Stew color** | | |
| - L* | 21.07 ± 0.03[b] | 29.13 ± 0.06[a] |
| - a* | 22.51 ± 0.03[a] | 21.86 ± 0.07[b] |
| - b* | 23.49 ± 0.24[b] | 29.24 ± 0.14[a] |
| - ΔE* | - | 9.92 ± 0.11 |
| **Pork texture** | | |
| - Hardness (N) | 45.02 ± 0.64[a] | 27.04 ± 1.61[b] |
| - Springiness index | 1.01 ± 0.01[ns] | 0.94 ± 0.09 [ns] |
| - Cohesiveness | 0.63 ± 0.01[a] | 0.28 ± 0.01[b] |
| - Chewiness (N) | 28.45 ± 0.73[a] | 7.21 ± 1.14[b] |
| - Shear force (N/mm.s) | 16.32 ± 0.27[a] | 7.30 ± 0.41[b] |

*Mean values in the same row with different superscript letters are significantly different ($p \leq 0.05$) by a paired t-test.
[ns] means that values in the same row are not significantly different ($p > 0.05$).

**Table 5.** Chemical changes of marinated pork stew in retort pouch

| Chemical changes | Before processing* | After processing* |
|---|---|---|
| Protein (g/100 g) | 16.09 ± 0.12[b] | 16.42 ± 0.11[a] |
| Fat (g/100 g) | 1.25 ± 0.02[b] | 1.42 ± 0.04[a] |
| Carbohydrate (g/100 g) | 7.37 ± 0.31[a] | 6.90 ± 0.28[b] |
| Ash (g/100 g) | 1.36 ± 0.06[a] | 1.33 ± 0.01[b] |
| Moisture content (%) | 73.93 ± 0.21[ns] | 73.93 ± 0.21[ns] |
| Water activity ($a_w$) | 0.97 ± 0.00 [ns] | 0.97 ± 0.00 [ns] |
| pH | 5.72 ± 0.02 [ns] | 5.74 ± 0.02 [ns] |

*Mean values in the same row with different superscript letters are significantly different ($p \leq 0.05$) by a paired t-test.
[ns] means that values in the same row are not significantly different ($p > 0.05$).

contents of the product. Thermal processing changed the complex meat system through the breakdown of muscle structure reflecting increased contents of protein and fat. This is in line with the assertion of Jiang *et al.* [33], who reported that prolonged high temperature cooking led to an increase in water-soluble protein contents due to the release of low molecular weight components in muscle. Girish *et al.* [12] also observed that water, soluble proteins and fats were displaced from the tissue when meat was cooked. Additionally, the results showed that there were no significant ($p > 0.05$) changes in moisture content, water activity ($a_w$) and pH after retort processing.

### 3.5 Acceptance and buying decision of marinated pork stew

Consumer acceptability scores of marinated pork stew by the elderly are presented in Figure 2. The overall liking score of this final product was liked moderately (7.56). In addition, acceptability scores for appearance, flavor, taste, tenderness and juiciness were also rated like moderately by elderly consumers as 7.22, 7.01, 7.11, 7.56 and 7.42, respectively. Ninety-four percent of the elderly consumers accepted the marinated pork stew in retort pouch. Eighty-six percent of the elderly consumers who responded “definitely would buy” and/or “probably would buy” were a measure of positive purchase intent for this product (data not shown). Thus, retort processing was used to alter texture of marinated pork in order to make the pork stew suitable for the elderly.

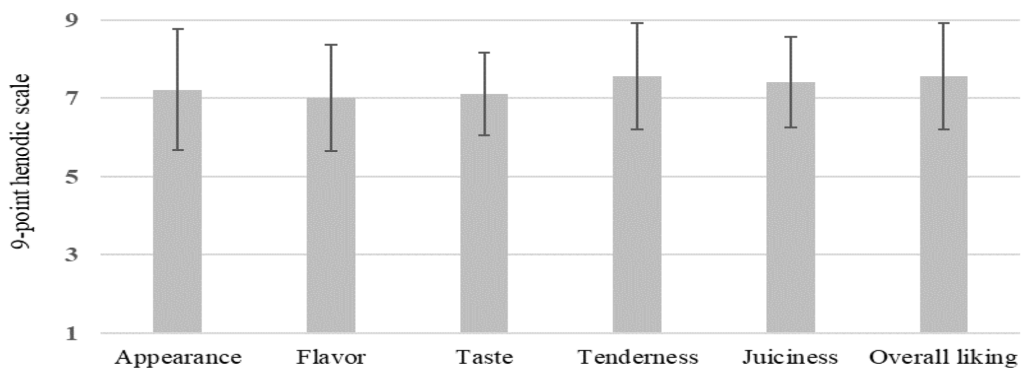


**Figure 2.** Consumer acceptance test of marinated pork stew in retort pouch

## 4. Conclusions

Based on the obtained results, pork meat showed quality improvement in color, cooking loss, cooking yield, texture and sensory characteristics after marinating with alkaline solutions, i.e. sodium chloride (M-SC), sodium bicarbonate (M-SBC) and sodium tripolyphosphate (M-STPP). M-SBC was the most effective for improving the texture of meat by raising its pH including hardness and shear force value. Furthermore, M-SBC marinated pork received the highest liking score of tenderness among all marinated pork types by the elderly. After retort processing of M-SBC pork, stew color had increased L* and b* values whereas it showed decreased a* value. The texture of marinated pork had improved as indicated by decreasing in hardness, cohesiveness, chewiness and shear force value. Furthermore, protein content of marinated pork stew had increased after thermal processing. The marinated pork stew in retort pouch provided food properties suitable for the elderly.

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