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Quality characteristics of retort samgyetang marinated with different levels of soy sauce and processed at different F_0 values

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Abstract

The aim of this study was to develop retorted samgyetang marinated with different levels of soy sauce and processed at different F_0 (thermal death time at 121℃) values. The tested marinade series comprised different percentages of soy sauce in water (0%, 25%, and 50% [w/w]) containing a fixed concentration of sodium tripolyphosphate (0.3% [w/w]). Following marination, samgyetang was prepared and subjected to retort processing, until an F_0 value of either 8 or 29 was achieved. Meat quality analysis of the breast meat, sensory evaluation, and aroma analysis were performed as indicators of acceptability. The meat pH decreased as the soy sauce content increased, regardless of the F_0 value. The shear force value significantly decreased as the concentration of soy sauce increased, but increased as the F_0 value increased ($p < 0.05$). Lipid oxidation was not affected by marination, but increased significantly as the F_0 value increased ($p < 0.05$). The proportion of polyunsaturated fatty acids decreased significantly ($p < 0.05$) as the F_0 value increased. The total alkane content decreased as the F_0 value increased ($p < 0.05$). Changes in the total volatile sulfur compound and 2-butyl-1-octanol content were affected by soy sauce marination. Marination using 25% soy sauce and retort sterilization, until an F_0 value of either 8 or 29 was achieved, improved the acceptability of samgyetang. Therefore, marination using 25% soy sauce and retort sterilization until an F_0 value of 8 is the process recommended for developing a soy sauce-flavored, retorted samgyetang product of acceptable quality.

Keywords: Samgyetang, Soy sauce, Volatile compounds, F_0 value, Marination

INTRODUCTION

As the dietary pattern of modern people has changed rapidly in recent times, a number of products in the form of home meal replacements (HMRs) have been introduced in the market. A retort pouch product is a type of HMR product that includes samgyetang, galbitang, curry, etc. Samgyetang is a

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Authors' contributions
Conceptualization: Kim J, Utama DT, Lee SK.
Data curation: Kim J, Jeong HS, Barido FH.
Formal analysis: Kim J.
Methodology: Kim J, Jeong HS, Barido FH.
Software: Kim J.
Validation: Utama DT, Lee SK.
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traditional Korean chicken soup made using herbs, ginseng, garlic, and other ingredients. Recently, samgyetang has been developed as an HMR product due to changes in consumer spending patterns [1,2]. In addition, retort pouched samgyetang was exported to the United States, Hong Kong, Taiwan, and Japan, with a total value of 11 million dollars [3]. Exported samgyetang can be distributed at room temperature for a long period of time by granting commercial sterilization during retrofit work [2]. However, some samgyetang manufacturers apply overheating treatment to control *Clostridium botulinum* spores [1].

In retort processing, the F_0 value represents the extent to which heat treatment at 121.1℃ affects microorganisms. The F_0 value is calculated using the following formula:

$$F_0 = \int_{t_0}^{t} L(t) \cdot dt = \int_{t_0}^{t} 10^{(\theta_t - 121.1)/z} \cdot dt = \int_{t_0}^{t} \frac{1}{F_1} \cdot dt$$

In this case, t_0 is the starting time for heat processing, t is the final time for heat processing, θ_t is the temperature for any heat treatment, z is the z value of the microorganism, and F_1 is the heating time corresponding to the effect of heating at any temperature (θ_t) to 121.1℃ for one minute. In other words, the combined value of the heat injection effect (L) required to reduce the number of microbes to the prescribed level at a given time is F_0, and is displayed as $L = 1 / Fi$ at $10\ (\theta_t - 121.1) / z = 1 / Fi$ [4].

High-temperature–high-pressure processing affects food safety due to its sterilizing effect against microorganisms in food; however, excessive heat treatment can easily break down the muscle structure and bones of the chicken carcass in samgyetang. Excessive heating results in damaged chicken meat and bone shape, affecting the texture quality, causing discoloration and off-flavor development and, finally, decreasing consumer preferences [5,6].

Curing and marination are processing methods applied in meat processing. They enhance the flavor, juiciness, and texture quality of meat products [7]. Salt and phosphate salt are typical curing agents. The salt extracts major proteins from meat and increases its binding capacity. In this way, the water holding capacity (WHC) of the meat is increased and water loss during cooking is reduced [8]. Alkaline phosphate is known to increase the pH of meat, thereby increasing the WHC and yield [9,10]. To date, numerous studies have reported the effect of salt on the quality of processed meat products, but recent studies have shown that excessive salt intake promotes cardiovascular disease. Some of the research groups reported the association between salt intake and hypertension and cardiac diseases [11,12]. Therefore, the food industry is seeking alternatives for processing that involve less salt. Soy sauce is considered a substitute for salt [13]. Soy sauce can be reducing the salt content and add a unique flavor [14]. Additionally, Yamaguchi and Takahashi [15] and Mojet et al. [16] reported that the umami taste of soy sauce and salt complement each other; the saltiness was enhanced by the umami sensation of soy sauce, even if the salt content decreased. The use of soy sauce as a curing agent for meat has many functional effects. According to Kim et al. [17] the shear force value of beef was reduced by soy sauce marination. This is because soy sauce increases the solubility of collagen, resulting in fragmentation of the muscle fiber. Additionally, according to Aoshima and Ooshima [18], soy sauce possesses antioxidant activity and contains a high polyphenol content (30.0 mM). Because of these antioxidants, the use of soy sauce with meat can inhibit certain processes at the beginning of storage, such as free radical scavenging activity and lipid peroxidation [17]. Therefore, soy sauce could be used in samgyetang manufacturing in the development of new variants with improved product functionality. Therefore, this study was conducted to observe the effect of soy sauce marination and the F_0 value on the flavor compounds, degree of oxidation, and microbiological safety of soy sauce-flavored retorted samgyetang.

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MATERIAL AND METHODS

Sample and broth manufacturing

Chilled chicken carcass (470 g) from semi-white broiler and frozen chicken feet (stored for less than 1 month) were purchased from a local distributor. Samgyetang chicken feet broth was prepared according to the method of Kim et al. [19]. To make the samgyetang broth, frozen chicken feet were thawed for 24 h in a chilling room (2℃) and were washed using flowing cold water to remove blood. All washed chicken feet were dried for 12 hours at 70℃ using a food dehydrator (LD-918BT, Liquip, Hwasung, Korea). Dried chicken feet, along with distilled water, were placed in an autoclavable glass bottle at a 1:8 ratio (w/v), and extracted using an autoclave (AC-13, Jeio Tech, Daejeon, Korea) for 1 h at 121℃ with a pressure of 1.5 kgf/cm^2. Chicken feet extracts were filtered out using a broth bag (18 cm × 28 cm, polyethylene, polypropylene Cleanwrap, Seoul, Korea), and the final broth was prepared by adding a small amount of salt, ginseng powder, garlic powder, and monosodium glutamate. The broth was maintained at 5℃ for 12 h before further use.

Soy sauce marination

Visible fats around the abdominal cavity were removed. The control group of this experiment was prepared by adding 0.3% (w/w) sodium triphosphate (STPP) to distilled water. In addition to STPP, the treatment groups contained either 25% (w/w) soy sauce in distilled water or 50% (w/w) soy sauce in distilled water. Chicken was soaked in marinade (150% of the chicken carcass weight) for one hour (each side for 30 min). Finally, the marinated chicken carcass was drained for 20 minutes on a wire mesh.

Manufacturing of samgyetang

The manufacturing process of retorted samgyetang, prepared according to different concentrations of soy sauce and F_0 values, is shown in Fig. 1. Garlic, glutinous rice, and dried jujube were wrapped

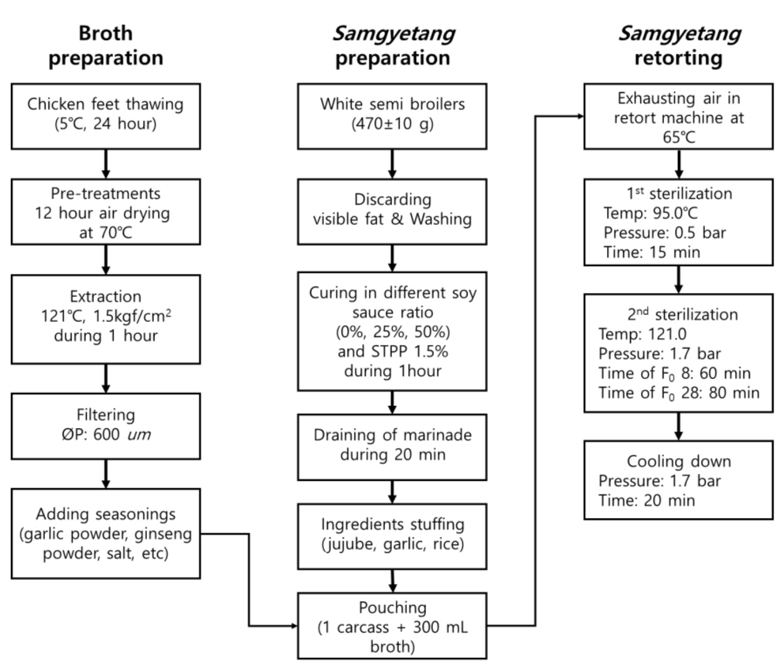

Fig. 1. Manufacturing procedure of soy sauce-marinated samgyetang.

with rice paper (Bich Chi Food Company, Sadec, Vietnam) and stuffed into the abdominal cavity of the marinated chicken carcass. After stuffing, the chicken was placed into a retort pouch (polypropylene, 19 cm × 25 cm) and 300 mL chicken feet broth was added. The pouch was sealed using a sealing machine at a sealing temperature of 250℃ (WB-1150VP, WB Tech, Goyang, Korea). After packaging was complete, the retort pouch was placed into a retort machine (STERI-ACE, Kyunghan, Kyungsan, Korea) and heated. The F_0 value was measured by inserting a retort machine temperature sensor into the legs and breast of a chicken packaged under the same conditions as the samples. Additionally, for more accurate F_0 value measurements, a data logger (EBI_TP11, Ebro, Xylem Analytics, Weilheim, Germany) was inserted into the abdomen of the chicken to measure the final F_0 value. After removing any air from the retort machine set at 65℃, the first sterilization was then performed at 95.0℃ and 0.5 bar for 15 minutes. The second sterilization process immediately followed the first, in which the F_0 value was set at 121.0℃ and 1.7 bar, and this process required 60 and 80 min to achieve an F_0 value of 8 and 29, respectively (Fig. 2). The first round of cooling was conducted at 1.7 bar for 20 min and was followed by a second round of cooling for one hour by soaking the samples in chilled water (4℃).

Physicochemical analysis

Proximate

The moisture content, crude fat, and crude protein were analyzed in triplicates using the AOAC method [20].

Meat color

Samgyetang breast meat was separated from the carcasses, and the sample surface and CIE L*, a*, and b* were measured at 10 different surface locations using a chroma meter (CR-400, Konica Minolta Sensing, Osaka, Japan). The chroma ($C^* [a^{*2} + b^{*2}]^{1/2}$) and hue-angle ($\tan^{-1} [b^* / a^*]$) values were calculated using the L*, a*, and b* values. Chroma meter calibration was conducted using a white plate (2° observer; Illuminant C: Y = 93.6, x = 0.3134, y = 0.3194).

pH

The samgyetang breast meat pH was measured in triplicates. Samples (5 g) in distilled water (50 mL) were homogenized using a homogenizer (PH91, SMT, Tokyo, Japan) operated at 10,000 rpm

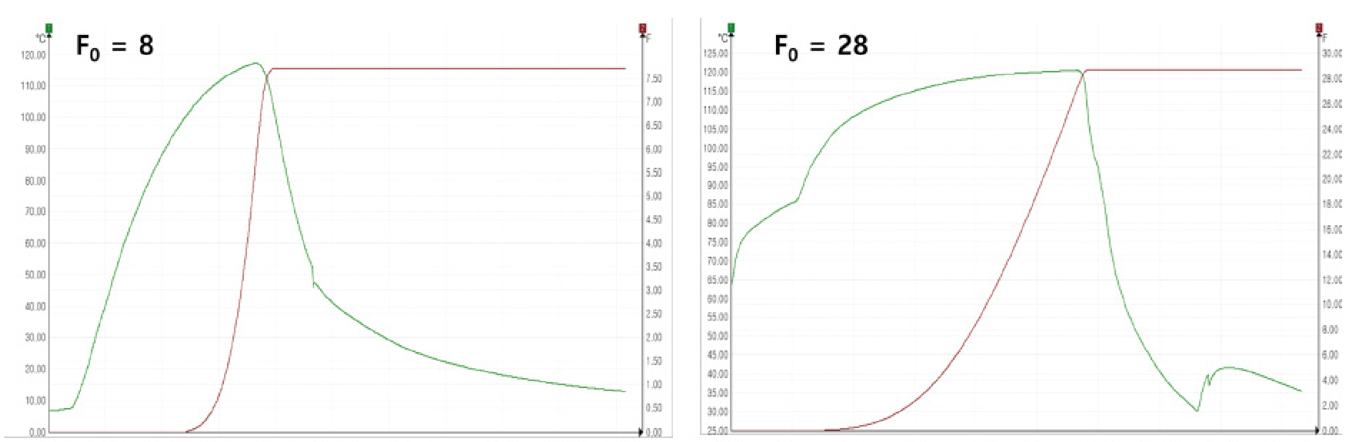

Fig. 2. The setting conditions of the retort process.

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for one minute. The slurry was stirred using a magnetic stirrer, and the pH was recorded using a calibrated pH meter (SenvenEasy pH, Mettler-Toledo GmbH, Greifensee, Zurich, Switzerland).

Bacterial counts

The total plate count (TPC) and anaerobic plate count were measured using the Food and Drug Administration (FDA) bacteriological analytical manual [21]. Meat samples (10 g) were placed in 90 mL of 0.1% peptone in a sterile bag (Whirl-pak blender bag, Nasco International, Fort Atkinson, WI, USA) and homogenized using a stomacher at a low speed (Laboratory blender400, Seward, West Sussex, UK) for one minute, followed by serial dilution of the samples. The pour plate technique was used to prepare the samples using plate count agar (Difco, USA). The media was incubated at 37℃ for 36 h. For anaerobic conditions, GasPak anaerobic atmosphere generation bags (Sigma-Aldrich, St. Louis, MO, USA) and an anaerobic chamber, the Anaerobic Pouch System (BD GasPak™, Franklin Lakes, NJ, USA) were used. The total bacterial counts were calculated as Log CFU/g.

2-Thiobarbituric acid reactive substances (TBARS)

Lipid oxidation was analyzed using the TBARS method of Sinhuber and Yu [22], with modifications. Samples (0.5 g) were prepared in triplicate and vortex-mixed with 3 mL of 1% TBA in 0.3% NaOH and 17 mL of 2.5% trichloroacetic acid in 36 mM HCl (Sigma-Aldrich, St. Louis, MO). The samples were heated in a water bath (BW-20 G, Biotechnical Services, San Diego, CA, USA) at 98℃ for 30 min and then immersed in ice water for 10 min. Subsequently, 5 mL of an aqueous sample was centrifuged at 2,800×g for 30 min at 4℃ (1248R, Labogene, Lillerød, Denmark). The absorbance of the clear pink layer was recorded at 532 nm (UV Mini 1240 PC, Shimadzu, Kyoto, Japan) against the blank. The result was expressed in milligrams of malondialdehyde (MDA) per kg of meat.

Fatty acid composition

The fatty acid composition was measured in triplicates. Fat extraction was performed according to a method described by Folch et al. [23]. Meat samples (10 g) were added to 25 mL of a chloroform–methanol solution and homogenized at 13,500 rpm for one minute using an ultra-homogenizer (T25 basic, Ika Werke Gmbh & Co., Staufen, Germany). After homogenization, the solution was added to 6 mL of 0.88% KCl and centrifuged at 2,400×g for 10 min. The layer of extracted fat in chloroform was filtered using filter paper (Whatman filter paper No. 1), and the chloroform was evaporated using a nitrogen gas evaporator (MGS-2200, EyelaTokyo Rikakikai, Tokyo, Japan) at 38℃. Fat was methylated using 25% BF_3. Fatty acid methyl esters were separated with 1 mL/min helium gas using gas chromatography (Table 1). The concentration of fatty acids in the samples was analyzed against the retention time of a standard (47015-U, Supelco, Bellefonte, PA, USA) and calculated as a percentage of the total peak area.

Shear force

Shear force tests were performed, with eight repetitions, using breast meat samples that were cut into 1 cm × 1 cm × 1 cm cubes. A texture analyzer (TA-XT2i version 6.06, Stable Micro Systems, Godalming, UK), equipped with a Warner–Bratzler shear blade, was used. The samples were cut against the muscle fibers. The analysis conditions were set as follows: load cell: 5 kg; pre-test speed: 5.0 mm/sec; test speed: 1.0 mm/sec; and post-test speed: 5.0 mm/sec. The analyzed results were calculated as kg force units.

Table 1. Gas chromatography conditions for fatty acid analysis

Item	Condition
Instrument	6890N (Agilent Technologies, Santa Clara, CA, USA)
Column	WCOT fused silica capillary column (100 m × 0.25 mm i.d., 0.20 μm film thickness, Varian, Lake Forest, CA, USA)
Injector temperature	250℃
Injection volume	1 μL
Split ratio	100:1
Carrier	Helium at 1.0 mL/min constant flow
Oven temperature	150℃ (1 min) → 200℃ (7℃/min) → 250℃ (5℃/min) → hold for 10 min
Detector temperature	FID, 275℃

FID, flame ionization detector.

Volatile flavor compounds

The analysis of volatile flavor compounds was conducted using 5 g of the ground breast meat samples in a 50 mL headspace vial pre-heated to 60℃ for 10 min. The flavor compounds were extracted using carboxen/polydimethylsiloxane (CAR/PDMS, Sigma-Aldrich, St. Louis, MO, USA) fiber (Ø = 75 μm) with 30 min of heating at 60℃. After extraction, the fibers were injected into the GC port set at 250℃, and the volatiles were desorbed for 5 min at a split ratio of 1:5. The DB5 fused silica column (30 μm × 0.25 mm i.d., 0.25 μm film thickness, J & W Scientific, Folcom, CA, USA) was used as a column in gas chromatography (7890A, Agilent Technologies, Santa Clara, CA, USA). The temperature of the oven was set to increase to 200℃, according to a program. The interface temperature and quadruple temperature were set to 280 and 150℃, respectively. The mobile phase was helium gas with a flow speed of 1 mL/min. Each volatile compound was detected using mass spectrometry (MS), where the ion source temperature of the MS was set to 280℃, with an electron impact of 70 eV. The scanning range of the MS was set to between 50 and 450 m/z, and the scan speed was set to 1 scan/sec. After detection, a standard library of National Institute of Standards and Technology (NIST) was used to identify any volatile compounds. In addition, a series of n-alkanes (C8–C20) were analyzed under the same conditions to obtain a retention index (RI) for the identified volatile substances. The RI was then compared to databases posted at Flavornet [24] and Foodb [25], each of which was presented by converting its per-peak area unit × 10^5/g (dry mass) into a % content.

Consumer preferences

Consumer preferences analysis was conducted using 30 untrained panelists. Samples were labeled using random 3-digit numbers. The sensory samples were stored at 5℃ prior to evaluation. Each sample was reheated using a microwave for 1 min (HS-XC365APB, Samsung Hauzen, Suwon, Korea, high frequency output: 800 W). A total of seven parameters were evaluated by panelists: appearance, taste, saltiness, flavor, texture, juiciness, and overall acceptance. The evaluation method used was a 7-point hedonic scale method: liked very much (7 points), liked a lot (6 points), liked (5 points), neither like nor dislike (4 points), disliked (3 points), disliked a lot (2 points), and disliked very much (1 point).

Quantitative descriptive analysis (QDA)

QDA was conducted using 10 trained panelists (five males and five females). The panel members who participated in the evaluation for the QDA were trained using breast meat of samgyetang, and the training session was conducted for a total of six hours for two weeks, three times per week.

The preparation of the samgyetang samples and the conditions of the sensory room were set in the same way as for the assessment of the consumer preferences. A description analysis was conducted with a total of five categories. The analysis items were umami, bitterness, saltiness, soy sauce flavor, and chicken flavor, and the scale of the sensory testing was evaluated using a seven-point hedonic scale. The standard material decision for each category was a modification of the method used in Adhikari et al. [26]. For the umami taste, monosodium glutamate diluted in bottled water was set as 4 points. The bitter taste was espresso diluted in water at a 1:8 (v/v) ratio and measured as 5 points. For saltiness, 0.5% salt water (w/v) was used as 3 points. The smell of soy sauce was used for soy sauce (Joseon soy sauce, No: 1986035805910, Sampyo, Seoul, Korea), and was set as 7 points. Chicken flavor was used by grinding the dried thighs at 70℃ for 12 h, and the score was set as 6 points.

Statistical analysis

The data obtained from the experiments were analyzed using the R statistical program (Version 3.4.3). The CRAN mirror and library USA (CA 1) and Agricolae were used. A two-way ANOVA test was performed to observe the effects of the F_0 value and soy sauce marination, followed by Duncan's multiple range test. Principal components analysis (PCA) was used to analyze the association between the aroma compounds, lipid oxidation, and sensory traits using devtools and ggbiplot libraries.

RESULTS AND DISCUSSION

Breast meat color

L* was significantly decreased ($p < 0.05$) in samples with a high soy sauce ratio with an increase in redness ($p < 0.05$) and yellowness ($p < 0.05$) (Table 2). The black color of soy sauce is the result of Maillard reaction between the free amino acids and sugar which mix during manufacturing. Kim et al. [17] reported that soy sauce marinade has the effect of decreasing the lightness and increasing the yellowness of beef patty. While the F_0 value does not affect lightness and yellowness, the redness was significantly lower in the F_0 29 samples than in the F_0 8 samples. Lee et al. [27] also showed similar results, i.e., that the redness of retorted samgyetang was decreased under high heating.

Proximate

Table 3 shows the proximate breast meat results of soy sauce marination of samgyetang with different F_0 values. In this study, the F_0 value and marinade ratio did not affect the samgyetang water content.

Moderate amounts of salt in meat are reported to increase the WHC by absorbing water and physically weakening the structure of muscle fibers, such as M-line and Z-line [28]. The protein content was significantly decreased at high concentrations of soy sauce compared to the control (p <

Table 2. The instrumental color of samgyetang (breast meat) prepared with different soy sauce amount ratios and F_0 values

Variable	F_0 8			F_0 28			SEM	*p*-value		
	0%	25%	50%	0%	25%	50%		Soy sauce	F_0	Inter (S/F_0)
L*	78.98^{a}	75.76^{b}	74.85^{b}	79.61^{a}	75.93^{b}	73.61^{c}	0.30	< 0.001	0.721	0.062
a*	2.80^{bx}	3.97^{ax}	4.44^{ax}	2.42^{cy}	3.64^{by}	4.17^{ay}	0.10	< 0.001	0.013	0.708
b*	17.95^{b}	19.97^{a}	20.06^{a}	17.14^{b}	19.99^{a}	20.02^{a}	0.21	< 0.001	0.451	0.393

[a–c]Mean values within each row with different superscripts are significantly different about marinade ratio ($p < 0.05$).

[x,y]Mean values within each row with different superscripts are significantly different about F_0 value ($p < 0.05$).

Inter (S/F_0), interaction *p*-value of the soy sauce concentration with the F_0 value.

Table 3. Proximate composition of samgyetang (breast meat) prepared with different soy sauce amount ratios and F_0 values

Variable	F_0 8			F_0 29			SEM	*p*-value		
	0%	25%	50%	0%	25%	50%		Soy sauce	F_0	Inter (S/F_0)
Moisture	69.52	70.51	70.62	70.36	70.49	70.47	0.170	0.151	0.511	0.233
Crude protein	27.07^{a}	26.14^{ab}	25.69^{b}	27.33^{a}	23.63^{b}	25.01^{b}	0.293	0.007	0.069	0.471
Crude fat	3.33	2.82	3.54	3.04	5.38	3.69	0.208	0.394	0.053	0.663

^{a,b}Mean values within each row with different superscripts are significantly different about marinade ratio ($p < 0.05$).

Inter (S/F_0), interaction *p*-value of the soy sauce concentration with the F_0 value.

0.05), which may be due to the relative increase in the moisture content resulting from marination and the external outflow of salt soluble proteins in soy sauce.

Physicochemical analysis

Table 4 shows the pH, lipid oxidation (assayed using TBARS), and shear force results for the different samgyetang preparations. The pH was significantly decreased in the 50% soy sauce treatment groups compared to the control group in the F_0 8 samples ($p < 0.05$). According to Fu and Kim [29], soy sauce contains acetic acid, lactic acid, succinic acid and pyroglutamic acid, which is slightly acidic, with a pH of 4–5. Shazer et al. [30] reported a pH decreasing in the manufacturing of soy sauce jerky product. Additionally, Kim et al. [17] reported a similar pH result, i.e., that it decreased in soy sauce-marinated beef meat. As the pH approaches the isoelectronic point, the WHC of the meat decreases, and water leaking occurs. As a result, the quality of the meat texture is reduced, resulting in a decrease of consumer preferences. In this experiment, the pH was slightly thought significantly reduced by increased soy sauce concentration in the marinade. however, soy sauce 25% group on F_0 29 showing a little different pattern.

Changes in TBARS values by addition of soy sauce c were not observed in this study, but the TBARS value was significantly increased as the F_0 value increased ($p < 0.05$). Many researchers have reported an increased TBARS values as a result of high F_0 values.

Lee et al. [2] reported that when retorted samgyetang was manufactured according to F_0 4, 7, and 10, the F_0 10 samgyetang had the highest TBARS value relative to a 0-day storage date as well as the fastest increase rate of lipid oxidation during storage. TBARS values can affect consumer acceptability. Tarladgis et al [31] had earlier reported a high correlation when evaluating the flavor of pork, due to detection of a rancid flavor as the TBARS content increases. Nam and Ahn [32] said that consumers would detect an off-flavor when the TBARS value was higher than 1 mg MA/kg. However, since none of TBARS value for the samples produced in their study exceeded 0.6, the determined threshold for perception, there were no problems concerning off-flavors.

The texture of samgyetang was significantly different, depending on the concentration of soy sauce and the F_0 value. Samgyetang meat and bones can be crushed due to a high temperatures and

Table 4. Physicochemical characteristics of samgyetang (breast meat) prepared with different soy sauce amount ratios and F_0 values

Variable	F_0 8			F_0 29			SEM	*p*-value		
	0%	25%	50%	0%	25%	50%		Soy sauce	F_0	Inter (S/F_0)
pH	6.45^{a}	6.38^{ab}	6.32^{b}	6.44^{b}	6.53^{a}	6.25^{c}	0.02	< 0.001	0.533	0.495
TBARS (mg/kg)	0.27^{y}	0.25^{y}	0.34^{y}	0.59^{x}	0.44^{x}	0.51^{x}	0.031	0.871	< 0.001	0.269
Shear force (kg)	1.47^{ay}	1.00^{by}	0.87^{cy}	1.63^{ax}	1.05^{bx}	1.00^{cx}	0.032	< 0.001	0.002	0.714

$^{a–c}$Mean values within each row with different superscripts are significantly different about marinade ratio ($p < 0.05$).

^{x,y}Mean values within each row with different superscripts are significantly different about F_0 value ($p < 0.05$).

Inter (S/F_0), interaction *p*-value of the soy sauce concentration with the F_0 value; TBARS, 2-thiobarbituric acid reactive substances.

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pressures during retort processing [6,27]. A poor texture negatively affects consumer selection of meat products, including samgyetang [33]. Thus, this weakening of meat texture is one of the problems that must be solved in retort foods.

As shown in Table 4, the increasing concentration of soy sauce reduced the shear-force of samgyetang breast meat compared to the control ($p < 0.05$). Kim et al. [17] reported similar results, indicating that reducing the shear force in soy sauce marinade affects beef meat and adding that this shear force reduction is the reason why soy sauce marination can increase the solubility of collagen and facilitate the fragmentation of myofibril. A high F_0 value was the effect of increasing the samgyetang shear force value ($p < 0.05$). These results were different from other similar studies. Krzywdzinska-Bartkowiak et al. [34] reported a decrease in shear force when beef was canned after salting and being cooked at a high temperature and pressure ($p < 0.05$). Majumdar et al. [35] manufactured a meat product, rohu balls, that were retorted at F_0 6, 7, and 9, and the hardness decreased as the F_0 increased ($p < 0.05$). Ali et al. [36] also reported decreased hardness with increased F_0 when canned sardines and pouches were manufactured according to F_0 of 5, 7, and 9. However, on our study, increasing the F_0 value resulted in a high shear force.

Microbial contents on samgyetang

A microbial test was conducted to detect TPC and anaerobic bacteria. In this study, the retort process at F_0 8 and F_0 29 led to sterilization of the sample. Thus, no bacteria were found (data are not shown). Retorted samgyetang that is processed using commercial sterilization can be stored for a long time at an ambient temperature [2]. However, some manufacturers apply overheating to prevent the growth of *Clostridium botulinum* spores [1].

Fatty acid composition

Table 5 shows the samgyetang fatty acid composition as a result of soy sauce marination and treated

Table 5. Fatty acid composition of samgyetang (breast meat) prepared with different soy sauce amount ratios and F_0 values

Compound	F_0 8			F_0 29			SEM	*p*-value		
	0%	25%	50%	0%	25%	50%		Soy sauce	F_0	Inter (S/F_0)
C14:0	1.37	1.39	1.33	1.49	1.44	1.94	0.08	0.260	0.091	0.181
C16:0	25.96	25.76	25.45	25.81	26.02	25.61	0.08	0.308	0.571	0.995
C16:1n7	5.73	4.96	5.67	5.60^x	6.23^x	6.14^x	0.10	0.308	0.008	0.206
C18:0	8.18^x	9.08^x	8.14^x	8.38^y	7.52^y	8.23^y	0.10	0.672	0.028	0.812
C18:1n9	39.65	38.34	39.08	39.72	39.90	38.87	0.17	0.088	0.159	0.733
C18:2n6	17.20^x	18.61^x	18.17^x	17.24^y	17.21^y	17.34^y	0.17	0.161	0.022	0.251
C18:3n3	1.09^y	0.95^y	1.00^y	1.09^x	1.16^x	1.01^x	0.02	0.059	0.042	0.851
C20:4n6	0.54^x	0.81^x	0.57^x	0.44^y	0.35^y	0.56^y	0.03	0.258	0.002	0.469
C20:5n3	0.28^x	0.40^x	0.28^x	0.24^y	0.18^y	0.29^y	0.02	0.440	0.006	0.455
SFA	35.51	35.92	35.23	35.67	34.97	35.78	0.12	0.783	0.754	0.540
MUFA	45.38^y	43.30^y	44.75^y	45.32^x	46.13^x	45.01^x	0.24	0.421	0.039	0.783
PUFA	19.11^x	20.78^x	20.01^x	19.01^y	18.90^y	19.21^y	0.19	0.190	0.010	0.401
n6	17.74^x	19.43^x	18.74^x	17.68^y	17.56^y	17.90^y	0.18	0.146	0.010	0.353
n3	1.37	1.35	1.28	1.33	1.34	1.31	0.02	0.204	0.788	0.436
n6/n3	13.04	14.44	14.74	13.37	13.23	13.79	0.24	0.065	0.190	0.259

^{x,y}Mean values within each row with different superscripts are significantly different about F_0 value ($p < 0.05$).

Inter (S/F_0), interaction *p*-value of the soy sauce concentration with the F_0 value; C14:0, myristate; C16:0, palmitate; C16:1n7, palmitoleate; C18:0, steariate; C18:1n9, oleate; C18:2n6, linoleate; C18:3n3, α-linolenate; C20:4n6, arachidonate; C20:5n3, eicosapentaenoic acid; SFA, saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

at different F_0 values. C14:0 (myristate), C16:0 (palmitate), C16:1n7 (palmitoleate), C18:0 (steariate), C18:1n9 (oleate), C18:2n6 (linoleate), C18:3n3 (α-linolenate), C20:4n6 (arachidonate), and C20:5n3 (Eicosapentaenoic acid [EPA]) were detected. Among the fatty acids, oleic acid (C18:1n9) levels were higher than any other fatty acid (38.34%–39.90% of all fatty acids). Additionally, 25.45%–26.02% palmitic acid (C16:0) and 17.20%–18.61% linoleic acid (C18:2n6) were detected. These results are very similar to the fatty acid compositions ordinarily found in chicken. In their study of broiler and Korean native chickens, Lee et al. [37] found palmitic acid (C16:0, 23%–28%), linoleic acid (C18:2n6, 13%–17%), and oleic acid (C18:1n9, 28%–34%) to be the major fatty acid components. In addition, saturated fatty acids (SFA) were found to be distributed at 34%–35%, monounsaturated fatty acids (MUFAs) the highest at between 43% and 46%, and polyunsaturated fatty acids (PUFAs) at 19%–20%.

The composition of fatty acids in samgyetang was not affected by soy sauce marination, although the F_0 level influenced the proportion of some fatty acids ($p < 0.05$). Palmitic acid, myristic acid, and stearic acid are SFA. Among them, palmitic acid and myristic acid were not affected by the F_0 value, but stearic acid was significantly different as by F_0 value changed ($p < 0.05$). In the case of MUFAs, oleic acid was not affected by either soy sauce marination or the F_0 value, but the palmitoleic acid was significantly higher in the F_0 29-treated samples ($p < 0.05$). Levels of PUFAs, including arachidonic acid, were significantly lower for higher F_0 values ($p < 0.05$). Kiyohara et al. [38] and Rikimura and Takahashi [39] reported that arachidonic acid contributes to the characteristic chicken flavor and ameliorates the umami taste.

Linoleic acid, α-linolenic acid, and EPA are a PUFA group. The total PUFA concentration was significantly decreased as the F_0 value increased ($p < 0.05$). A high temperature and high pressure resulted in PUFA oxidation and decomposition in samgyetang meat. The reason for the decrease in PUFAs in retorted samgyetang were found to be a direct effect of high pressure and high temperature on lipid oxidation and decomposition. Linoleic acid cannot be synthesized in the body and is therefore an essential fatty acid that is a precursor of arachidonic acid [40]. This acid can decompose into benzaldehyde, 2-nonenal, 2-heptanal, and 2-octenal when heated [41,42]. Of these, benzaldehyde is reported to have a cherry and almond flavor [43]. Increases in the temperature and pressure resulted in changes to the PUFA, n-6 fatty acid, and MUFA contents. Changing the composition of fatty acids is found to have an effect in changing flavor compounds and promoting fat oxidation during product storage.

Sensory analysis and flavor compounds

Consumer acceptability test

Table 6 shows the consumer acceptability test results. The appearance score for samgyetang was significantly increased as the F_0 value increased ($p < 0.05$). The addition of soy sauce in marination increased the taste, flavor, juiciness, and overall acceptance ($p < 0.05$). However, no differences were observed between the different levels of soy sauce.

Quantitative descriptive analysis (QDA)

QDA is an evaluation that distinguishes between standard materials and samples. Table 7 shows the QDA results according to 10 trained panelists. Each panelist appraised the umami, bitterness, saltiness, soy sauce flavor, and chicken meat flavor of the sample. According to the panelists, there were no sensory quality differences related to the taste due to F_0 changes during the heating process of samgyetang. Further, the bitterness, umami, and chicken flavor were also not affected by the soy sauce ratio. However, soy sauce affected the saltiness and soy sauce flavor, where the 0% soy sauce group was found to be less salty than the other groups. Soy sauce contains numerous substances

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Table 6. Consumer acceptance of samgyetang prepared with different soy sauce amount ratios and F_0 values

Variable	F_0 8			F_0 29			SEM	*p*-value		
	0%	25%	50%	0%	25%	50%		Soy sauce	F_0	Inter (S/F_0)
Appearance	4.60^{y}	4.30^{y}	4.40^{y}	5.15^{x}	5.05^{x}	4.95^{x}	0.11	0.434	0.004	1.000
Taste	3.85^{b}	4.65^{a}	4.40^{ab}	4.00^{b}	5.15^{a}	4.80^{ab}	0.13	0.028	0.160	0.681
Saltiness	4.35	5.10	4.60	3.75	5.15	4.55	0.12	0.071	0.397	0.342
Flavor	4.00^{b}	4.75^{a}	4.85^{a}	3.80^{b}	4.85^{a}	4.80^{a}	0.11	< 0.001	0.815	0.775
Texture	3.75^{b}	4.60^{a}	4.70^{a}	4.00^{b}	5.35^{a}	4.70^{ab}	0.11	0.002	0.119	0.631
Juiciness	3.55^{b}	4.25^{ab}	4.90^{a}	3.30^{b}	5.10^{a}	4.60^{a}	0.12	< 0.001	0.658	0.928
Overall acceptance	3.75^{b}	4.60^{a}	4.55^{a}	3.70^{b}	5.30^{a}	4.80^{a}	0.11	< 0.001	0.168	0.572

Hedonic scale: 1, dislike very much; 2, dislike moderately; 3, dislike slightly; 4, neither like nor dislike; 5, like slightly; 6, like moderately; 7, like very much.

^{a,b}Mean values within each row with different superscripts are significantly different about marinade ratio ($p < 0.05$).

^{x,y}Mean values within each row with different superscripts are significantly different about F_0 value ($p < 0.05$).

Inter (S/F_0), interaction *p*-value of the soy sauce concentration with the F_0 value.

Table 7. Quantitative descriptive analysis of samgyetang prepared with different soy sauce amount ratios and F_0 values

Variable	F_0 8			F_0 29			SEM	*p*-value		
	0%	25%	50%	0%	25%	50%		Soy sauce	F_0	Inter (S/F_0)
Umami	3.45	4.05	3.95	3.45	3.90	3.75	0.14	0.251	0.725	0.774
Bitterness	3.05	2.90	3.05	2.60	3.30	2.90	0.14	0.675	0.819	0.675
Saltiness	2.20^{b}	3.25^{a}	3.95^{a}	1.85^{b}	3.55^{a}	3.40^{a}	0.16	< 0.001	0.506	0.786
Soy sauce flavor	3.40^{b}	4.05^{a}	4.20^{a}	2.95^{b}	3.55^{a}	3.85^{a}	0.14	0.015	0.127	0.885
Chicken meat flavor	2.65	2.85	2.85	2.85	3.15	2.90	0.15	0.742	0.555	0.844

^{a,b}Mean values within each row with different superscripts are significantly different about marinade ratio ($p < 0.05$).

Inter (S/F_0), interaction *p*-value of the soy sauce concentration with the F_0 value.

that contribute to flavor development. Feng et al. [44] reported that soy sauce flavor compounds include ethanol, 2-methyl-1-propanol, 2-methyl-1-butanol, 3-methyl-1-butanol, 1-octen-3-ol, 2-phenylethanol, 2-methylpropanal, 2-methylbutanal, 3-methylbutanal, benzene acetaldehyde, acetic acid, ethyl acetate, guaiacol, 4-ethylguaiacol, 2-methylpyrazine, 2,5-dimethylpyrazine, 2,3,5-trimethylpyrazine, 2,5-dimethylfuran, furfural, 2-furanmethanol, 5-methyl-2-furancarboxaldehyde, 3-phenylfuran, dimethyl disulfide, dimethyl trisulfide, 3-(methylthio) propanal, and maltol. During marination, these flavor compounds are transferred to the chicken and thus enhance the acceptability. Therefore, using soy sauce marination could increase the consumer acceptability of samgyetang. The saltiness strength was increased as the soy sauce level was increased.

Flavor compounds

Table 8 shows the differences in flavor compounds as a result of soy sauce marination. A total of 18 flavor compounds was detected. Each flavor compound was classified into six groups: aldehydes, alkanes, benzenes, furans, volatile sulfur compounds (VSCs), and alcohols. Among the total volatile compounds, the total alkane content was significantly influenced by the F_0 value, while the total VSC and total alcohol contents were significantly different according to the different soy sauce marination ratios ($p < 0.05$). The total aldehyde was detected at 22.97%–34.81% for each treatment but there were no differences according to different soy sauce ratios and F_0 values. Aldehyde was generated under conditions of lipid oxidation. A lot of aldehyde can produce a rancid flavor, cardboard off-flavor, and grass odor. Eight types of aldehyde were detected and in the case of 2-methylbutanal, heptanal, octanal, and propanal, their levels significantly differed depending on the soy

Table 8. Aroma volatiles composition (% unit) of samgyetang prepared with different soy sauce amount ratios and F_0 values

Group	Compound	F_0 8			F_0 29			SEM	*p*-value			Aroma description	References
		0%	25%	50%	0%	25%	50%		Soy sauce	F_0	Inter (S/F_0)		
Aldehydes	Butanal	1.86	2.00	1.61	1.70	2.05	2.05	0.056	0.708	0.304	0.028	Pungent, green, malty, meaty, nutty, bready	[24], [25]
	2-Methylbutanal	0.58^{b}	0.96^{a}	1.02^{a}	0.75^{b}	0.80^{b}	1.52^{a}	0.062	< 0.001	0.087	0.191	Almond, cocoa, coffee, nutty	[25]
	3-Methylbutanal	0.41^{by}	0.69^{ax}	0.74^{ay}	0.62^{bx}	0.62^{by}	1.07^{ax}	0.041	< 0.001	0.019	0.419	Aldehydic, fatty, malt, chocolate	[25]
	Hexanal	25.19	21.54	22.35	27.81	16.71	25.69	0.833	0.238	0.826	0.863	Grass, tallow, fat	[24], [25], [53]
	Heptanal	0.59^{a}	0.58^{a}	0.49^{b}	1.11^{a}	0.34^{c}	0.55^{b}	0.041	< 0.001	0.094	0.007	Oily, fatty, citrus, rancid	[24], [25], [53]
	Octanal	0.26^{b}	0.24^{b}	0.34^{a}	0.47^{a}	0.20^{b}	0.23^{b}	0.016	0.012	0.393	< 0.001	Oily, fatty, green, honey	[24], [25], [53]
	Nonanal	0.34	0.18	0.27	0.34	0.16	0.29	0.014	0.092	0.973	0.841	Fatty, citrus, grassy, green	[24], [25], [53]
	Propanal	2.60^{bx}	3.01^{ax}	2.83^{abx}	2.01^{by}	2.09^{aby}	2.64^{ay}	0.093	0.036	0.001	0.324	Cocoa, pungent, nutty, alcoholic, wine	[24], [25], [53]
Alkane	2,5-Dimethylheptane	5.13^{ax}	2.52^{bx}	0.49^{cx}	0.27^{aby}	0.21^{by}	0.32^{ay}	0.271	< 0.001	< 0.001	< 0.001	Bacon, meaty, gravy, roasted	[25]
	Heptane	5.18	4.82	5.07	5.54	3.05	5.38	0.183	0.767	0.331	0.952	Alkane, ethereal, sweet	[25]
	Octane	2.11^{b}	2.19^{b}	3.75^{a}	2.93^{a}	0.99^{b}	4.08^{a}	0.254	0.026	0.977	0.686	Alkane, gasoline	[24], [25]
Benzene	Toluene	25.58	36.43	39.84	33.85	50.26	32.28	1.733	0.121	0.146	0.055	Sweet, paint, solvent-like	[24], [25], [54]
	2-Methylfuran	8.29	8.56	8.65	7.02	8.43	7.38	0.444	0.747	0.331	1.000	Acetone, chocolate	[25]
Furans	2,5-Dimethylfuran	0.45^{bx}	0.64^{ax}	0.65^{ax}	0.42^{by}	0.36^{by}	0.61^{ay}	0.025	< 0.001	0.012	0.973	Bacon, meaty, gravy, roasted	[25]
	2-Pentylfuran	2.11	2.00	2.27	2.75	0.46	2.75	0.144	0.889	0.454	0.573	Beany, butter, green	[25]
VSC	Carbondisulfide	18.05^{a}	11.11^{b}	6.91^{c}	10.52^{b}	12.35^{a}	9.78^{c}	0.738	< 0.001	0.334	< 0.001	Pleasant, sweet, ether like	[51]
	Benzothiazole	0.94^{b}	2.15^{ab}	2.40^{a}	1.40^{b}	0.69^{b}	3.35^{a}	0.209	< 0.001	0.966	0.595	Gasoline, coffee, cooked, meat, nutty, sulfur	[24], [25]
Alcohol	2-Butyl-1-octanol	0.33^{b}	0.41^{a}	0.33^{b}	0.49^{a}	0.24^{b}	0.28^{b}	0.018	0.012	0.439	0.011	-	-
Total aldehydes		31.83	29.19	29.65	34.81	22.97	34.04	0.870	0.504	0.831	0.749	-	-
Total alkane		12.41^{x}	9.52^{x}	9.31^{x}	8.75^{y}	4.24^{y}	9.78^{y}	0.479	0.324	0.002	0.052	-	-
Total benzene		25.58	36.43	39.84	33.85	50.26	33.28	1.733	0.121	0.146	0.055	-	-
Total furan		10.85	11.19	11.56	10.18	9.25	10.48	0.446	0.650	0.180	0.852	-	-
Total VSC		18.99^{a}	13.25^{b}	9.31^{c}	11.92^{b}	13.04^{a}	13.13^{a}	0.738	0.009	0.363	< 0.001	-	-
Total alcohol		0.33^{b}	0.41^{a}	0.33^{b}	0.49^{a}	0.24^{b}	0.28^{b}	0.018	0.012	0.439	0.011	-	-

[a–c]Mean values within each row with different superscripts are significantly different about marinade ratio ($p < 0.05$).

[x,y]Mean values within each row with different superscripts are significantly different about F_0 value ($p < 0.05$).

Inter (S/F_0), interaction *p*-value of the soy sauce concentration with the F_0 value.

VSC, volatile sulfur compound.

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sauce concentration. Likewise, levels of 3-methylbutanal were significantly affected by changes in the F_0 value ($p < 0.05$). 2-Methylbutanal and 3-methylbutanal are known to have almond, nut, cocoa, coffee, and oily flavors. These compounds were more frequently detected in marination with 50% soy sauce than with 25% soy sauce ($p < 0.05$). 2-Methylbutanal and 3-methylbutanal are the main flavor compounds of soy sauce [44]. The reason for the significantly increase in 2-methylbutanal and 3-methylbutanal during marination with 50% soy sauce is judged to be the transfer of the scent from soy sauce itself to the chicken meat. Heptanal, octanal, and nonanal are known as lipid oxides. These compounds have a specific odor that has been described as rancid, lipid, waxy, and grassy, in addition to a burnt flavor [45].

There were 3 compounds (2,5-dimethylheptane, heptane, and octane) identified in the alkane group. Total alkanes and 2,5-dimethylheptane were significantly high in the F_0 29 group. Alkanes are generated by decarboxylation from long-chain fatty acids and affect the flavor of food, because these compounds possess a high olfactory threshold [46,47]. 2,5-Dimethylheptane is known to have specific flavors such as bacon, meat, gravy, and roasting flavors. On the other hand, octane is described as having a gasoline flavor [48]. In this study, octane levels were higher in the 50% soy sauce marination treatments ($p < 0.05$) than for all other samples.

Toluene (methylbenzene) was the only identified benzene that occupied 25.58%–50.26% of the total identified volatiles. Toluene has a sweet, paint, solvent-like odor [49]. However, amount of toluene was not significantly affected by the treatments.

Total furan was detected at 9.25%–11.56% in each treatment. In the F_0 8 group, the 2,5-dimethylfuran content was significantly higher compared to the control without the addition of soy sauce and the F_0 29 group. There was also a significant increase in 2,5-dimethylfuran as the soy sauce concentration was increased. Feng et al. [44] reported that 2,5-dimethyl furan is one of the compounds contributing to the soy sauce flavor.

Total VSC contents differed for each soy sauce marination group. VSCs are one of the common volatile ingredients in food, and have been reported to include more than 700 kinds of organic compounds [50]. In this experiment, two types of VSCs were found: carbon disulfide and benzothiazole. According to Holleman et al. [51], carbon disulfide is known to have a sweet and ether-like odor. Marchiels et al. [52] reported that benzothiazole produces scents associated with stews, with a gravy and roasted meat flavor. Benzothiazole was significantly increased as the soy sauce concentration increased in both F_0 8 and F_0 29 ($p < 0.05$).

There was only one identified alcohol, 2-butyl-1-octanol, and this accounted for 0.24%–0.49% of the total identified volatiles. 2-Butyl-1-octanol levels were associated with the F_0 value ($p < 0.05$).

Fig. 3 shows the principal component analysis (PCA) results for 18 volatile compounds, 6 consumer test variables (taste, salty, flavor, texture, juiciness, and overall acceptance), 3 QDA variables (umami, saltiness, and chicken flavor strength) and TBARS data.

The PCA plot describes the relationship between the selected variables, such as lipid oxidation (TBARS value), volatile compounds, sensory traits and the treatment itself. About 38.5% of the data variability was explained by principal component 1, and 14.8% of the data variability was explained by principal component 2. In total, only 53.3% of the variability was explained using this 2-dimensional plot. The proportion (%) is similar to that of the linear regression (r) between only two variables: the higher the value, the stronger the correlation is between variable 1 and 2, or the relationship is more linear. However, when we use multi-variables, as in this case (TBARS value, volatile compounds, and sensory traits), 90% is very rarely achieved, and a simple linear regression is not possible. The arrow shows a positive (higher) value and the circles with different colors represent each treatment group.

Lipid oxidation is observed to be closely related with HM1 and HM3 or the groups with higher

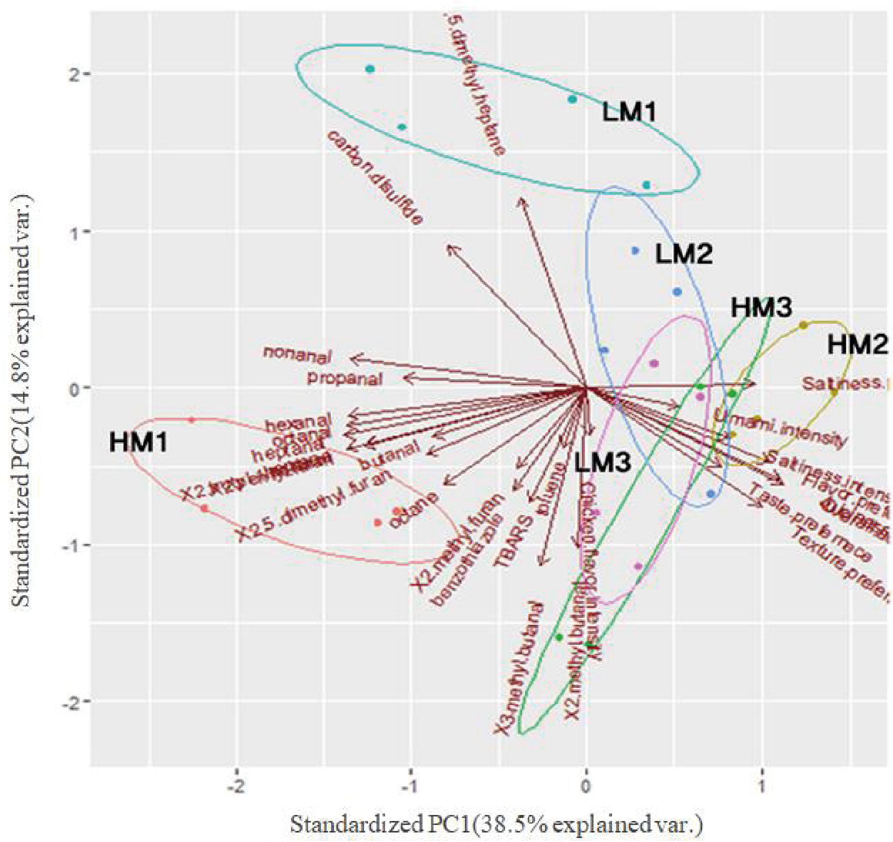

Fig. 3. Principal component analysis (PCA) plot of samgyetang prepared with soy sauce, including the ratios and F_0 values, using the 2-thiobarbituric acid reactive substances (TBARS) value, volatile compounds, and sensory traits as loading plots. L, low F_0 value (F_0 8); H, high F_0 value (F_0 29); M1, 0% soy sauce; M2, 25% soy sauce; M3, 50% soy sauce.

F_0. Regardless of the F_0 value (L or H), groups that were marinated with soy sauce M2 and M3 are closely related with sensory traits such as umami intensity, saltiness, and preferences, while LM1 and HM1 (non-marinated groups) were showed not close relationship with sensory traits and were thus less preferred. LM1 is associated with 2,5-dimethylheptane and carbon disulfide (sulfuric aroma) while HM1 is associated with aldehydes and furans. Therefore, marination positively affected preferences, while a higher F_0 value increased lipid oxidation. In addition, a high abundance of volatile compounds was not positively correlated with preferences.

CONCLUSION

Soy sauce could be used as an alternative to salt as a curing substance during samgyetang marination. In the case of a high F_0 value, the shear force (tenderness) was negatively affected and induced lipid oxidation of the final product. In conclusion, marination using 25% soy sauce and retort sterilization until an F_0 value of 8 is recommended for developing a soy sauce-flavored retorted samgyetang product with an acceptable quality.

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