Quality Characteristics of Fermented Sausage Prepared with Soy Sauce

Seon-A Yoo, Seong-Eun Park, Seung-Ho Seo, and Hong-Seok Son*

School of Oriental Medicine, Dongshin University, Naju, Jeonnam 58245, Korea

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*Corresponding Author
Tel: +82-61-330-3513
Fax: +82-61-330-3519
E-mail: hsson@dsu.ac.kr

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Abstract The contributions of soy sauce to the quality characteristics of fermented sausages were investigated. The number of lactic acid bacteria in sausages prepared with soy sauce increased from the first day of fermentation, and the population reached approximately log 7 CFU/g by the 5th day of fermentation. The pH decreased sharply to 5.0-5.1 by the 5th day of fermentation, in accordance with the dramatic increase of titratable acidity. After 36 days of fermentation, the levels of total organic acids and amino acids in soy sauce sausages increased to 3,026.3-3,116.4 mg/100 g and 1,132.2-1,172.8 mg/100 g respectively, and this level was even higher than those of the sausage fermented with a starter culture. 2% soy sauce sausage also showed higher values of hardness, chewiness, and smoke odor than the control. These results suggest that soy sauce has great potential as an alternative starter culture and additive for the quality improvement of fermented sausages.

Keywords: fermented sausage, soy sauce, amino acid, organic acid, lactic acid bacteria

Introduction

Fermented sausages are obtained through fermentation of a meat batter composed of lean and fat meat, combined with salts, nitrite (curing agent), sugars and spices as non-meat ingredients and stuffed in natural or synthetic casings. The sausage is then subjected to a ripening process under controlled temperature and relative humidity (RH) (1). The need for safe products without any contamination from undesired microorganisms has led in the use of starter cultures for the manufacture of fermented sausages (2,3). Among the starter culture options, lactic acid bacteria (LAB) are the most widely used for the manufacture of fermented sausages, because the use of LABs has an advantage of hygienic properties through pH reduction and the production of antimicrobials (4). LAB such as *Lactobacillus* and *Pediococcus* is commonly used starter culture for the production of high quality products (5).

As the interest in starter cultures for sausage fermentation has increased, many studies have been reported about the isolation, selection, identification, and application of starter cultures for the production of fermented sausage. On the other hand, many scientists have recently presented detailed studies involving the addition of fermented foods as a substitute for starter culture in the process of making fermented sausage. According to Park and Lee (6), the addition of kimchi to the sausage mixture prior to fermentation produced the microbiological stability required for fermented sausages. Coloretto *et al.* (1) reported that the addition of wine to

sausages immediately reduced the pH and inhibited the growth of undesirable microflora. The strains from other fermented foods can give unexpected positive effects such as decreasing the initial pH, changing the microbial community, increasing proteolytic activity, and reducing nitrates to nitrites in fermented sausages, compared to the strains from meat. The addition of fermented food can also have synergistic effects on the aroma, taste and biological activity in fermented sausage. For example, the effects of wine on fermented sausage aroma profiles are well known, and several local commodities in Italy produced using wine during mixing can be found (1). Thus, it is worthwhile to continue the search for alternative starters to prevent the growth of food pathogens in sausages as well as to enhance the quality of fermented sausage.

Soy sauce is a common traditional seasoning in Asian regions for improving the flavor and taste of food (7). Soy sauce contains complex mixture of metabolites, including salt, peptides, free amino acids, organic acids, and free sugars, derived from the soybean and/or wheat (8). Korean traditional soy sauce is manufactured through high salt brine fermentation using *meju* (a fermented soybean block) without any other starters, leading to the growth of various microorganisms derived from the surrounding environment including incubation shelves, air, and rice straws (9,10). *Bacillus* in bacteria and *Mucor*, *Geotrichum*, and *Aspergillus* in fungi are dominant during *meju* fermentation (11). Successively, in soy sauce production using *meju*, enzymic hydrolysis, lactic acid fermentation and ethanol fermentation of the mash take place in a batch process

over a period of 6 months (12). Although most bacteria are unable to grow under such harsh conditions (15–20% of salt), halophilic lactic acid bacteria and yeast play active roles in deepening the taste and emphasizing the aroma of soy sauce (13,14).

This is the first study on the application of soy sauce in fermented sausage production. The aim of this work was to evaluate how the incorporation of soy sauce affects the quality in fermented sausage. Therefore, soy sauce was substituted for the starter culture during the production of fermented sausages. The contributions of soy sauce to the quality characteristics of fermented sausages were monitored compared to the sausages fermented with a starter culture.

Materials and Methods

Preparation of starter cultures In our previous study, we selected the most suitable starter culture (*L. plantarum* MLK 14-2) isolated from kimchi (15). Kimchi is a traditional fermented Korean side dish made of vegetables with a variety of seasonings contains many LAB such as *L. plantarum*. Based on the results of the study, MLK 14-2 was considered to have high potential as a starter culture for making fermented sausages (16). The strain was inoculated into de Man, Rogosa Sharpe (MRS) broth and grown at 37°C for 48 h. Cultures were then harvested by centrifugation (10,000×g, 5 min). Concentrated cells were washed twice in saline water (0.85 g/100 mL), and finally re-suspended at 4°C in protective medium (20% sucrose and 0.85% NaCl) at a ratio of a 1:2. The final protected bacterial suspensions were lyophilized in a freeze-dryer (Cleanvac 8; Hanil, Incheon, Korea) and stored at 4°C for use as a starter culture.

Fermented sausage manufacture Three separate batches of fermented sausages, about 20 kg each, were prepared and the fermented sausages were processed. The ingredients used were pork (3×5 cm) 54% (w/w), beef (3 mm) 32% (w/w) and lean pork 14% (w/w). The pork and beef were obtained from a local retailer in Jeju (Korea) and trimmed of all visible fat and connective tissues. Garlic (1 g/kg) and NaNO₃ (50 mg/kg) were added to the meat mixture of production batches. Batches were named according to the additive: (i) Control, with 0.05% (w/w) of *L. plantarum* MLK 14-2, (ii) S2%, with 2% of soy sauce (v/w), and (iii) S3%, with 3% of soy sauce (v/w). The soy sauce used in this study was purchased from a local market in Jeju (Korea). The pH of the soy sauce was 5.23, and titratable acidity as lactic acid was 1.40% with 23.0% of salt content. The viable cell numbers of yeast and LAB in the soy sauce were log 5.99 CFU/mL and log 6.68 CFU/mL respectively. The mixtures were stuffed into a fibrous casing, at approximately 300 g each. The processing was done at 18±0.1°C and 70±0.5% RH for 4 days; 19±0.1°C and 73±0.5% RH for 4 days, and finally 20±0.1°C and 85±0.5% RH for 28 days. Three samples from each treatment were collected on days 1, 3, 6, 9, 15 and 36 of ripening for chemical and microbiological analyses.

Microbiological analysis Ten grams of fermented sausage were aseptically transferred into a conical tube and homogenized with 90 mL of sterilized saline water (0.85% NaCl). The homogenate was prepared using a rotor-stator homogenizer (X360; Pronextech, Seoul, Korea) prior to the preparation of 1/10 serial dilutions for microbiological analysis. LAB count was determined after growing LAB in MRS agar (Difco, Sparks, MD, USA) and incubating at 37°C for 48 h. Tests for every sample were carried out in duplicate and the results were expressed as log CFU/g.

Preparation of fermented sausage Ten grams of fermented sausage in 90 mL of distilled water were macerated with a homogenizer and extraction was carried out using a shaking water bath (HB-205SW; Hanbaek, Bucheon, Korea) for 1 h at 30°C. After centrifuging for 5 min at 4,000×g, the supernatant liquid from each extract was filtered through a 0.45 µm membrane (Whatman No. 2) and used in all the test systems.

Physico-chemical analysis pH was determined using a pH meter (pH-250L; ISTEK, Seoul, Korea) and the means of three measurements were recorded. The titratable acidity (TA) in samples was measured by the method of AOAC and expressed as % lactic acid based on dry weight (17).

Color measurements were carried out using a colorimeter (JP/CM-3500D; Minolta, Osaka, Japan) with illuminant. The colorimeter was calibrated using standard white and black plates (L* 96.97, a* 0.09, b* 0.16). The samples were sliced and wrapped with a single layer of stretch film after the application of slight pressure to obtain a uniform, bubble-free surface. It was ensured that there was no gap between the sample surface and the film, and the colorimeter readings were carried out on the surface of the wrapped samples. Six readings were taken and averaged for each sample.

Texture profile analysis (TPA) of the samples was performed at room temperature using a GB/TA. XT plus texture analyzer (Zwick Roell Z0.5; Minolta) equipped with a cylindrical probe of 50 mm in diameter. After discarding the external layer of the sausage, the samples (six cylinders), approximately 1 cm thick and 3 cm in diameter, were equilibrated to room temperature and compressed twice to 50% of their original thickness.

Organic acids and free amino acids analysis All standards and extract samples were filtered through a 0.2 µm membrane filter (Millipore, Billerica, MA, USA) prior to HPLC analysis. The levels of organic acid were analyzed using a liquid chromatography (LC) apparatus (LC-10Avp; Shimadzu, Kyoto, Japan) equipped with a Supelcogel C610-H column (300 mm×7.8 mm, Supelco, Richmond, PA, USA) and a Shimadzu SPD-10Avp detector. The column and detector were adjusted to a temperature of 30°C. Twenty microliters each of the samples and standards was injected into the column. Elution was carried out at a flow rate of 1.0 mL/min with 0.1% H₃PO₄ as the mobile phase.

The free amino acids concentrations in the samples were analyzed using liquid chromatography (Agilent 1100 Series; Agilent, Santa Clara, CA, USA) with an Agilent 1100 diode array detector (338 nm, Ref 390, 20 nm). Separation was achieved using ODS Hypersil column (150×4.6 mm i.d., particle size 3 µm, Thermo Scientific, Waltham, MA, USA) with a column oven temperature of 40°C. For the automated o-phthalaldehyde (OPA) derivatization, the HPLC's autosampler (G1329A; Agilent) injection program was used. The mobile phase was composed of (A) 10 mM Na₂HPO₄-10 mM Na₂B₄O₇, pH 8.2 and (B) MeOH-MeCN-DW (45:45:10, v/v/v) with a flow rate of 1.3 mL/min. The solvent program was used as follows: 5 min solvent B 4%, 22 min solvent B 50%, constant at solvent B 50% until 26.5 min, sudden drop to solvent B 4% at 27 min, and then constant at solvent B 4% for 3 min (total 30 min). For the analyses, all chemical reagents were of analytical grade. Standard compounds for organic acids and amino acids were purchased from Sigma-Aldrich (St. Louis, MO, USA).

Sensory analysis The quantitative descriptive profiles of the samples were determined using the final products to evaluate the sweet, salty, sour, and bitter taste as well as the smoke odor and off flavor of the sausages. Sensory analysis was performed by a 20-member panel (50% male/females, age range between 20 and 34 years). The panelists were served with sliced (approx. 0.5 mm thickness) fermented sausage, one per treatment, together with room temperature water to clean the palate between samples. The response to each treatment was determined as the mean value of the responses from all the panelists using a likert scale with scores from 0 (low) to 9 (high).

Statistical analysis Statistical analyses were performed using the SPSS version 14.0 statistical package for windows (SPSS Inc., Chicago, IL, USA). ANOVA and Duncan's multiple range tests were applied to the data to determine significant differences, and a value of $p < 0.05$ was considered statistically significant.

Results and Discussion

Microbiological analysis Figure 1 shows the growth kinetics of LAB during the ripening of fermented sausages with soy sauce and *L. plantarum* MLK 14-2 (Control). As expected, the counts of LAB were higher in the sausages with *L. plantarum* than in those with soy sauce after 1 day of fermentation. The number of LAB increased from the first day of fermentation, and the population reached approximately log 7-8 CFU/g in all lots by the 5th day of fermentation. In particular, dramatic increase in the LAB population was observed in the sausages with soy sauce. The rapid growth of the LAB may explain the reduction in pH. LAB population decreased to log 6 CFU/g in all tested samples by the 10th day of fermentation, and the growth remained constant or decreased slightly throughout the remaining

Fig. 1. Viability (log CFU/g) of lactic acid bacteria during ripening of fermented sausages without and with soy sauce.

ripening period. According to Hammes *et al.* (18), the stability observed for the counts of LAB during ripening and storage could be explained by LAB becoming the dominant microbe.

Physico-chemical analysis Figure 2 shows the changes in the pH and titratable acidity (TA) during sausage fermentation with *L. plantarum* and soy sauce. The pH value in fermented sausages on the 1st day of fermentation was in the 5.79-5.98 range, and the value decreased until 5th day of fermentation (Fig. 2A). Although a large and rapid decrease in pH at the early stage of fermentation was observed in the sausages inoculated with *L. plantarum*, the final pH of the tested samples showed similar values of 4.98-5.02. After 10 days of fermentation, the pH of the control sausage increased slightly throughout the remaining fermentation period. These may be due to meat protein degradation, which has a buffering effect on the organic acids produced during fermentation by LAB (19,20).

The pH of sausages with soy sauce was 5.0-5.1 by the 5th day of fermentation, which was lower than those (pH 5.4-5.9) of sausages treated with five types of commercial starter cultures, with the exception of one starter culture (pH 4.5) (21). The rapid growth of LAB at the early stage of fermentation resulted in decreasing the pH of the fermented sausages, which was responsible for the inhibition of undesirable bacteria, such as Enterobacteriaceae (19).

In general, the change of TA in the fermented sausages is inversely proportional to the pH change. As expected, the fermented sausages with *L. plantarum* showed a rapid increase of TA with a final TA value of 1.16% (Fig. 2B). The TA of the sausages with soy sauce, although slightly lower in the initial samples, showed a similar final value of 1.10-1.12%.

In this study, the pH decreased sharply in all samples, in accordance with the dramatic increase of LAB during the early stages of fermentation. The pH reduction may have originated from the production of lactic acid by LAB. The pH reduction ability of LAB

Fig. 2. Change in pH (A) and titratable acidity (B) during ripening of fermented sausages without and with soy sauce.

during early stage of fermentation are essential requirements for making safe products (4). Since the pasteurization of meats is not conducted prior to the fermentation of sausages, the growth of undesired bacteria such as *E. coli* is frequently detected with spontaneous fermentation (22). A rapid LAB growth and acidification were observed in the fermented sausages with soy sauce, suggesting

that it would have an advantage on the hygienic properties of the fermented sausages.

Organic acids analysis The organic acid contents of the fermented sausages on the 1st and 36th days of fermentation are shown in Table 1. Lactic acid level in fermented sausages is the main factor responsible for the reduction of pH and the increase of TA (23). It was clear that the acidification in sausages fermented with *L. plantarum* was stronger than that in sausages with soy sauce at the early stage of fermentation (Day 1). It is interesting to note that the lactic acid content of the sausages with 3% soy sauce was lower than that of the control batches; this low value was consistent with the TA profile shown in Fig. 1. However, in samples with 3% soy sauce, the levels of lactic acid increased from 971.2 mg/100 g, to 2,835.0 mg/100 g during the 36 days of fermentation, and this level was even higher than the levels (2,357.1 mg/100 g) of the control ($p < 0.05$). Although most organic acids in the sausages with soy sauce contained similar or lower concentrations compared to control on the first day of fermentation, there was a large increase in most organic acids ($p < 0.05$), with the exception of fumaric acid, in the sausages fermented with soy sauce over the course of fermentation. Unlike the other organic acids, fumaric acid content decreased to less than 0.1 mg/100 g in all samples.

Free amino acids analysis The gradual degradation of meat protein during fermentation resulted in higher levels of free amino acids (FAA) at the end of the manufacture are typical of fermented sausages (24). To investigate the effects of fermentation period and soy sauce addition on protein degradation, the free amino acids (FAA) analysis was conducted. Table 2 shows the identified amino acids by LC and their levels on the 1st and 36th day of fermentation. Initial levels of total FAAs were about 533.3-773.5 mg/100 g in all samples. The increase in total FAAs concentration during ripening for all the samples is in agreement with other studies (25,26). Although total FAAs concentration in the fermented sausages with soy sauce was lower than those in control at the 1st day of fermentation, higher total FAAs concentration was observed in the fermented sausages

Table 1. Organic acid contents of fermented sausages without and with soy sauce on the 1st and 36th days of fermentation

Organic acids (mg/100 g)	Day 1			Day 36		
	Control ¹⁾	S2%	S3%	Control	S2%	S3%
Oxalic acid	3.0±0.2 ^{a2)}	5.1±0.7 ^b	2.3±0.1 ^a	4.2±1.1 ^a	8.0±0.7 ^b	6.9±0.4 ^b
Citric acid	14.1±1.0 ^a	33.5±1.4 ^c	18.3±0.3 ^b	13.5±0.8 ^a	67.8±2.6 ^c	58.1±1.3 ^b
Malonic acid	16.5±0.4 ^b	19.2±0.2 ^c	11.9±0.2 ^a	15.2±1.4 ^a	44.9±2.9 ^c	37.9±0.7 ^b
Lactic acid	1,260.9±26.9 ^b	1,273.6±59.1 ^b	971.2±41.3 ^a	2,357.1±32.8 ^a	2,884.6±28.8 ^b	2,835.0±39.5 ^b
Fumaric acid	1.6±0.1 ^c	1.4±0.1 ^b	1.0±0.1 ^a	0.1±0.0 ^a	0.1±0.0 ^b	0.1±0.0 ^b
Pyroglutamic acid	1.6±0.1	1.8±0.2	1.6±0.1	13.7±1.0 ^a	25.7±2.2 ^b	22.6±2.3 ^b
Acetic acid	26.8±0.6 ^c	16.5±0.0 ^b	15.5±0.3 ^a	58.8±0.2 ^a	85.3±0.3 ^c	65.8±0.3 ^b
Total	1324.5	1351.1	1021.8	2462.6	3116.4	3026.3

¹⁾Control, with starter culture; S2%, with 2% of soy sauce; S3%, with 3% of soy sauce

²⁾Means in the same column followed by different letters are significantly different by Duncan's multiple range test ($p < 0.05$).

with soy sauce after 36 days of fermentation ($p<0.05$). These results may be due to active protein degradation of the proteinase-producing halophilic LAB from soy sauce during ripening (27).

Among the 18 FAAs detected in the initial meat mixture, Cys was the highest, followed by Tau and Val, all at concentrations over 50 mg/100 g of sausage. On the other hand, the FAAs predominant in the fermented sausages after 36 days of fermentation were Cys, Tau, Glu, Asp, Val, Met, Leu, Ile, and Phe at concentrations greater than 50 mg/100 g of sausage. It is interesting that Cys and Tau, which were abundant on the first day of fermentation, decreased during fermentation. Although there was a variation in specific amino acids and differences of degree, many studies have also reported increases in FAAs (16,25,28). The variations of FAA patterns in sausages indicate the differences in metabolic activity between the cultures during fermentation (29). In this regard, protein degradation in sausages fermented with soy sauce indicates its potential utility as a starter culture in the production of fermented sausages.

Color, texture, and sensory analysis Table 3 shows the results of the color, texture, and sensory analysis of fermented sausages on the 36th day of fermentation. The substitution of soy sauce affected the appearance of the fermented sausages. In particular, white fat granules were not observed inside the fermented sausages. Lightness (CIE L*-value) decreased with the addition of soy sauce, and the treatment with starter culture had the highest lightness ($p<0.05$). A similar result was observed in cooked meat patties prepared with soy sauce, and these differences were due to the unique color properties of soy sauce (30). Fermented sausages with 3% soy sauce had

marked lower value in red color (CIE a*-value) compared with the control ($p<0.05$), but there was no significant difference between the sausages with 2% soy sauce and the control. A difference in yellowness (CIE b*-value) between the control and the sausages with soy sauce was observed ($p<0.05$) and these results were attributed to the brown color of the soy sauce. Color is an important quality factor for consumers and changes of color resulted from soy sauce addition may affect consumer acceptability. A great variation in the color parameters of fermented meat products has been reported (31). These variations could be due to the composition of the products, the size of the meat particles, and the ripening time, suggesting that soy sauce can be incorporated into the product with any changes in color.

There were no significant differences in springiness, juiciness, sweetness, sourness, bitterness and off flavor between the fermented sausages. In contrast, there were significant differences in hardness, chewiness, and smoke odor ($p<0.05$). Generally, major changes in the fermented sausage structure take place during fermentation when the pH decrease and the myofibrillar proteins aggregate to form a gel (32). The fermented sausages prepared with soy sauce had higher values in hardness and chewiness than the control. Mora-Gallego *et al.* (33) reported that the addition of sunflower oil to fermented sausages decreased hardness, chewiness and cohesiveness which may decrease the consumer acceptability. However, excessive proteolysis in fermented sausages may have a negative effect on the texture (34). The hardness of soy sauce sausages in this study seems to have been caused by the salty conditions. During fermentation, the salty environment resulting from the addition of soy sauce leads

Table 2. Free amino acid contents of fermented sausages without and with soy sauce on the 1st and 36th day of fermentation

Free amino acids (mg/100 g)	Day 1			Day 36		
	Control ¹⁾	S2%	S3%	Control	S2%	S3%
Lysine	3.3±0.1 ^b	3.0±0.2 ^{a2)}	2.8±0.1 ^a	29.1±0.7 ^c	24.1±1.1 ^a	28.1±0.5 ^b
Arginine	5.4±0.2 ^c	3.4±0.1 ^b	2.2±0.0 ^a	4.1±0.0 ^a	7.6±0.4 ^b	6.6±0.1 ^a
Glycine	12.2±0.7 ^b	10.0±0.9 ^a	9.7±0.2 ^a	42.4±1.5 ^a	23.0±0.5 ^b	26.6±0.8 ^c
Cystine	320.0±8.9 ^c	279.6±10.0 ^b	260.0±3.6 ^a	178.1±3.4 ^c	145.1±3.6 ^a	161.0±5.1 ^b
Serine	12.4±0.3 ^b	11.0±0.7 ^a	10.6±0.3 ^a	38.0±1.6 ^b	32.2±0.9 ^a	41.1±1.4 ^c
Asparagine	5.9±0.2 ^a	6.4±0.3 ^b	5.5±0.2 ^a	34.9±1.6 ^a	32.5±1.0 ^b	33.8±0.5 ^b
Taurine	156.1±7.2 ^c	130.7±3.9 ^b	115.5±2.8 ^a	100.7±9.2 ^b	127.4±8.5 ^b	110.6±7.7 ^a
L-Alanine	18.0±1.0 ^c	13.8±0.3 ^b	13.3±0.2 ^a	37.0±2.6 ^a	42.3±1.0 ^b	40.3±1.4 ^b
Threonine	4.1±0.1	4.2±0.1	4.0±0.3	20.7±0.4 ^a	21.1±0.4 ^b	21.6±0.9 ^b
Glutamic acid	27.2±1.0 ^a	32.2±0.7 ^b	27.0±0.6 ^a	56.7±0.9 ^a	107.5±1.1 ^c	101.5±1.7 ^b
Aspartic acid	2.1±0.1 ^a	2.4±0.1 ^b	2.0±0.2 ^a	51.2±2.7 ^a	47.7±0.8 ^b	54.4±4.0 ^c
Proline	7.3±0.4	7.4±0.6	7.6±0.2	30.2±0.9 ^a	33.3±1.8 ^b	34.1±1.0 ^b
Valine	126.1±1.7 ^c	115.5±7.0 ^b	12.6±0.5 ^a	90.7±1.3 ^a	97.2±1.8 ^b	104.3±2.6 ^c
Methionine	12.8±1.7 ^b	11.9±0.8 ^{ab}	9.8±0.4 ^a	65.6±1.9 ^c	64.8±1.4 ^b	72.9±0.7 ^a
Leucine	10.5±0.1 ^b	11.7±0.1 ^c	9.3±0.1 ^a	67.3±0.6 ^a	83.8±2.6 ^b	85.5±1.7 ^b
Isoleucine	24.1±1.2 ^b	24.3±1.1 ^b	19.6±0.5 ^a	131.8±3.0 ^a	144.2±1.5 ^b	153.7±1.7 ^c
Tyrosine	7.0±0.3 ^b	7.4±0.4 ^b	5.5±0.6 ^a	1.7±0.3 ^c	15.8±0.2 ^b	7.7±0.2 ^a
Phenylalanine	18.7±0.4 ^b	21.6±1.2 ^c	16.3±0.5 ^a	78.1±1.0 ^a	82.7±0.9 ^b	88.9±2.3 ^c
Total	773.5	696.6	533.3	1058.4	1132.2	1172.8

¹⁾Control, with starter culture; S2%, with 2% of soy sauce; S3%, with 3% of soy sauce

²⁾Means in the same column followed by different letters are significantly different by Duncan's multiple range test ($p<0.05$).

Table 3. Analysis of texture, color, and sensory properties of fermented sausages without and with soy sauce

	Control ¹⁾	S2%	S3%
CIE color values			
L*	48.82±0.25 ^c	46.58±0.34 ^b	44.99±0.82 ^{a2)}
a*	10.76±0.25 ^b	10.87±0.11 ^c	8.86±0.42 ^a
b*	8.14±0.25 ^a	9.37±0.26 ^b	9.11±0.35 ^b
Texture analysis			
Hardness	5.84±0.50 ^a	6.16±0.22 ^{ab}	6.80±0.55 ^b
Chewiness	4.52±0.48 ^a	5.90±0.55 ^b	6.36±0.60 ^b
Springiness	5.02±1.37	4.80±1.00	4.81±1.10
Juiciness	5.78±0.60	4.70±0.82	4.84±0.79
Sensory analysis			
Sweetness	2.34±0.43	2.26±0.32	2.26±0.21
Saltiness	6.82±0.94	6.34±0.40	6.86±1.29
Sourness	5.86±1.80	4.42±1.70	4.56±0.98
Bitterness	2.26±0.93	2.02±0.31	2.34±0.46
Smoke odor	5.54±0.46 ^b	6.50±0.62 ^c	4.50±0.50 ^a
Off flavor	2.58±1.15	1.98±0.89	2.40±0.96

¹⁾Control, with starter culture; S2%, with 2% of soy sauce; S3%, with 3% of soy sauce

²⁾Means in the same column followed by different letters are significantly different by Duncan's multiple range test ($p<0.05$).

to an increase in the dryness and hardness of the fermented sausage. Decreases in hardness, as a consequence of salt reduction, have also been reported in frankfurters and bologna (35,36). In general, chewiness is related to hardness, as it is the product of hardness, cohesiveness and springiness. Lee *et al.* (37) also reported that sausages with kimchi powder were harder and chewier than the control. As expected, the sausages with soy sauce had higher values for chewiness value ($p<0.05$). The 2% soy sauce sausages had the highest value for smoke odor among the samples ($p<0.05$), while sweetness, saltiness, sourness, bitterness and off flavor levels showed no significant differences.

We examined the effect of soy sauce as a starter culture and an additive on the microbiological and physico-chemical characteristics of fermented sausages. In this study, pH decreased sharply in the sausages with soy sauce, in accordance with the dramatic increase of lactic acid bacteria during the early stages of fermentation. Significantly higher amounts of organic acids and amino acids were detected in the sausages prepared with soy sauce after ripening. Moreover, different characteristics were observed in the color and texture of the sausages with soy sauce. In conclusion, soy sauce was found to have high potential as an additive in the production of fermented sausages with varying quality.

Disclosure The authors declare no conflict of interest.

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