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ARTICLE

Quality Properties of Beef Jerky Replaced Salt with Soy Sauce, Red Pepper Paste and Soybean Paste during Storage

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Abstract

The aim of this study was to investigate the quality properties of beef jerky replaced salt with soy sauce, red pepper paste, and soybean paste. The quality properties of beef jerky including final water activity (a_w), moisture content, pH, color, shear force, total plate counts, thiobarbituric acid reactive substance (TBARS) values, and sensory evaluations were investigated. The sliced beef samples were marinated in salt (control), soy sauce (T1), red pepper paste (T2), and soybean paste (T3) for 24 h and then dried at 70°C for 6-8 h. The water activity of finished beef jerky varied from 0.72 to 0.70. The water activity for control and T1 samples decreased more rapidly as drying proceeded up to 6 h. The samples with salt replacement showed a lower pH and lightness than the control ($p<0.05$). The T1 sample showed a significant decrease in total plate counts after 21 d of storage ($p<0.05$). The TBARS for all treatments increased with storage days ($p<0.05$). The TBARS were significantly lower in T2 and T3 samples compared to control and T1 until 21 d of storage ($p<0.05$). The samples with salt replacement showed a lower intensity of saltiness than the control. Sensory evaluations found that the replaced soy sauce of beef jerky samples had better overall acceptability scores than the other treatment samples. It was concluded that replacing salt with soy sauce can delay lipid oxidation and enhance the sensory acceptance of beef jerkies.

Key words: beef jerky, replaced salt, soy sauce, red pepper paste, soybean paste

Introduction

Jerky is made from sliced whole muscles which have been marinated and dried. Also, jerky products can be made with various marinade techniques, meats from different species and drying conditions (Yang *et al.,* 2009). It is relatively simple to process, with a typical flavor, and usually requires no refrigeration during commercial distribution, due to low water activity. The final product reaches a water activity of 0.70-0.75 when it is ready for consumption, and is normally shelf stable for 6 months if left packed to inhibit microbial activity (Torres *et al.,* 1994). Hurdles to microbial survival and growth include drying temperature, low water activity, and preservatives such as salt and organic acids depending on the composition of the marinate mixture (Gailani and Fung, 1986; Quinton *et al.,* 1997).

Salt (sodium chloride) is one of the most frequently used ingredients in meat processing. Salt affects the flavor, texture and shelf life of meat products. Besides the perceived saltiness, salt brings out the characteristic taste of the meat product enhancing the flavor (Gillette, 1985). In particular, salt produces a strong decrease in water activity and high osmotic pressures (Lazarides *et al.,* 1995). However, the meat industry has explored various options to lower sodium in processed meats. An increased effort has been made to reduce the amount of salt in foodstuffs (Costa-Corredor *et al.,* 2009). The World Health Organization (WHO) has also recommended a reduction of salt content of meat products (WHO, 2007). There is a trend to reduce the salt content in foods because excessive sodium intake contributes to high blood pressure in salt susceptible consumers (Hee and Mac Gregor, 2010). A possible approach to reduce the sodium content is the partial and total replacement of sodium chloride with other chloride salts (KCl, $CaCl_2$ and $MgCl_2$) or phosphates (Sofos, 1989; Terrell, 1983). However, these techniques have different questions like the possible reduction

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of the salty flavor (metallic and bitter), anomalous color and textures, and microbiological stability (Toldrá, 2006).

In Korea, fermented soybean foods such as *doenjang* (soybean paste), *ganjang* (soybean sauce) and *gochujang* (red pepper paste) have been a major source of protein in the Korean diet (Cho *et al.*, 2009). Organic acids occur in fermented products as a result of hydrolysis, biochemical metabolism and microbial activity (Shukla *et al.,* 2010). Kremer *et al.* (2009) demonstrated that soy sauce could possibly achieve a reduction of salt in foods without leading to significant losses in taste intensity or product appreciation. Also, soy sauce is a healthy salt replacement (Keast and Breslin, 2002), as it is a flavor enhancer and modifier.

Therefore, the objective of this study is to investigate the effect of replacing salt with soy sauce, red pepper paste and soybean paste on the physicochemical and sensory properties of beef jerky, and to determine if curing agents can be effectively utilized for beef jerky processing.

Materials and Methods

Preparation of pork jerky samples

A total of three cattle (Korean native cattle, Hanwoo, market weight 425-475 kg) were randomly selected at a commercial slaughter plant. The muscle of beef *semimembranosus* was dissected from the carcasses 48 h postmortem. All subcutaneous and intermuscular fat and visible connective tissue were removed from the fresh muscles. The sample was sliced to 0.5 cm thick pieces with a meat slicer (HFS 350G, Hankook Fujee Industries Co. Ltd., Korea). Sliced jerky samples were cut parallel in the same direction as muscle fibers. Commercial salt, soy sauce, red pepper paste and soybean paste were purchased from a local food additives plant. Salt, soy sauce, red pepper paste and soybean paste solution were diluted with ice water for adding the same salinity content. In cause, the red pepper paste and soybean paste solutions were homogenized with a Polytron homogenizer (T25-B, IKA Sdn. Bhd., Malaysia) at 8,000 rpm for 30 s. The slurry was filtered through two layers of cheese cloth to remove the impurities. Prior to the processing of beef jerky, the salinity of salt, soy sauce, red pepper paste and soybean paste were adjusted. The sliced samples were then cured for 12 h in a cure solution containing 10% water, 2% salt solution (soy sauce, red pepper paste and soybean paste), 6% sugar, 0.2% pepper, and 0.028% sodium nitrate (based on raw meat weight; v/w).

After curing, all samples were dried using a dryer (DS80-1, Dasol Scientific Co. Ltd., Korea) at a temperature of 70°C. There was adequate air distribution between samples receiving the same drying treatment. Water activity measurements were then taken, to the target a_w<0.75. After drying and cooling to ambient temperature the jerky samples were packed (single package) and placed at room temperature (25°C) for 21 d.

Analytical methods

Salinity

The salinity was measured a digital salinity meter (Takemura, TM-30D, Japan). Approximately 3 g of the jerky sample was cut into small pieces and 27 mL of distilled water was added. Slurry was then made using a homogenizer (T25basic, IKA, Malaysia) and salinity was recorded.

Water activity (a_w) and moisture content

Three pieces of the beef jerky samples from each treatment were selected and cut into fine pieces using sharp scissors. The pieces were filled into water activity cups, and their water activity was measured with a water activity meter (AQS-2, Nagy mess system, Germany), calibrated at ambient temperature 20°C with distilled water (a_w=1.000) and saturated solutions of NaCl (a_w=0.756) and KCl (a_w=0.853).

Moisture content was determined according to AOAC (2000). The strips were dried in an air oven at 102°C for 24 h and the total moisture content of individual beef strips was determined from their pre-dry and dry weights expressed as the percentage of pre-dry weight and gram water per gram of dry weight.

pH

The pH was measured in triplicate using a digital pH meter (MP230, Mettler, Switzerland). Approximately 3 g of the jerky sample was cut into small pieces and 27 mL of distilled water was added. Slurry was then made using a homogenizer (T25basic, IKA, Malaysia) and pH was recorded. The pH meter was calibrated daily with standard buffers of pH 4.0 and 7.0 at 25°C.

Instrument color (lightness)

The surface lightness color value of the jerky samples were measured by the CIE L^* system using a Minolta Chroma meter CR-200 (Minolta Camera Co., Osaka, Japan), whereby measurements are standardized with respect to a white calibration plate (L^*=89.2, a^*=0.921 and

b^*=0.783).

Shear force

Shear force (kg/cm^2) was measured using the Instron Universal Testing Machine (Model 3343) with a V-shaped shear blade. From four samples, 0.5×4.0 cm (approximately 2.0 cm^2) cross sections (across to the fibers) were cut for cutting force measurements. The pork jerky samples were placed at right angles to the blade. The crosshead speed was 100 mm/min and the full scale load was 50 kg.

Microbiological analysis

On days 0, 7, 14 and 21 of storage, 25 g of jerky sample were aseptically removed from the packages and placed into whirl pack (stomacher) bags (Nasco, Ft. Atkinson, WI, USA) with 225 mL of 0.1% buffered peptone water and buffered to a pH of 7 with sodium hydroxide. Samples were then stomached in a Stomacher (78860, Interscience, France) for 2 min and serial dilutions were made. For microbial analysis, 1 mL of stomached and diluted sample was plated in duplicate on aerobic count plate Petri film® (3M Health Care, USA), according to manufacturer directions. Aerobic count plate film was then incubated at 37°C for 48 h in an incubation chamber (J070217, Jeio Tech, Korea). Counts were recorded as colony forming units per gram.

Lipid oxidation

The 2-thiobarbituric acid-reactive substance (TBARS) content of jerky samples from each treatment was determined using the TBA distillation procedure by Yang *et al.* (2009) as modified from a procedure by Sinnhuber and Yu (1977). A 0.4 g sample of jerky was weighed into a 30 mL screw capped pyrex tube (PYREX®, USA). Two to 3 drops of antioxidant solution (A: 0.3 g butylated hydroxyl anisole + 5.4 g propylene glycol, B: 0.3 g butylated hydroxyl toluene + 4.0 g tween 20), 3 mL TBA (thiobarbituric acid) solution, and 17 mL TCA-HCl solution (trichloroacetic acid + 0.6 N HCl) were added. The mixture was vortexed and then incubated in a 100°C boiling water bath for 30 min to develop color. The sample was cooled in cold water for 10 min. A 5 mL supernatant solution was transferred to the 10 mL glass tube, 2 mL of chloroform was added and centrifuged for 15 min at 2,000 *g*. The absorbance of the resulting supernatant solution was determined at 532 nm against a blank sample containing all the reagents minus the sample.

$$\text{TBARS (mg malonaldehyde/kg sample)} = \{(\text{absorbance sample} - \text{absorbance blank}) \times 46\} / \{\text{sample weight (g)} \times 5\}$$

Sensory evaluation

Eight panelists composed of faculty members and students from GNU (Gyeongsang National University) were trained in 3 training sessions. The panelists were given samples representing anchor points for attributes, and training sessions using beef jerky.

The panelists evaluated the samples for appearance, color, off-flavor, tenderness, juiciness, saltiness, and overall acceptability using a 9-point hedonic scale as described by Meilgaard *et al.* (2007). The panelists evaluated each characteristic of the sample using a 9-point hedonic scale, where 1 meant "extremely dislike" and 9 meant "extremely like." The saltiness was marked 1 for "weak" and 9 for "strong."

Statistical analysis

Data from three replications were analyzed by analysis of variance (ANOVA) using statistical analysis systems (SAS). ANOVA was adopted for designing the mathematical model using SAS 9.2 (SAS Institute, Inc., USA). Duncan's multiple range tests were used to determine the statistical significance among the means (SAS, 2008) at a significance level of 95%.

Results and Discussion

Water activity and moisture content

The experimental data on water activity and moisture content of beef jerky were obtained during drying at 70°C, after salt, soy sauce, red pepper paste and soybean paste treatments. The decreases in water activity for beef jerky in relation to drying time were shown in Fig. 1. Jerky is also relatively simple to process, has a typical flavor, and needs no refrigeration during commercial distribution due to its low a_w (Yang *et al.,* 2009). In general, the water activity for all beef jerky samples slowly decreased during drying for up to 4 h, and the water activity of all the samples rapidly decreased after 4 h of drying time (p< 0.05). The water activity of finished beef jerky varied from 0.72 to 0.70 (p<0.05). The ultimate a_w of control and T1 samples after 6 h of drying was satisfied being 0.70 and 0.72, and the ultimate a_w of T2 and T3 samples after 8 h of drying was satisfied being 0.71 and 0.70. Fluctuations in a_w between treatments were probably due to variation among the different curing agents. Also, the a_w

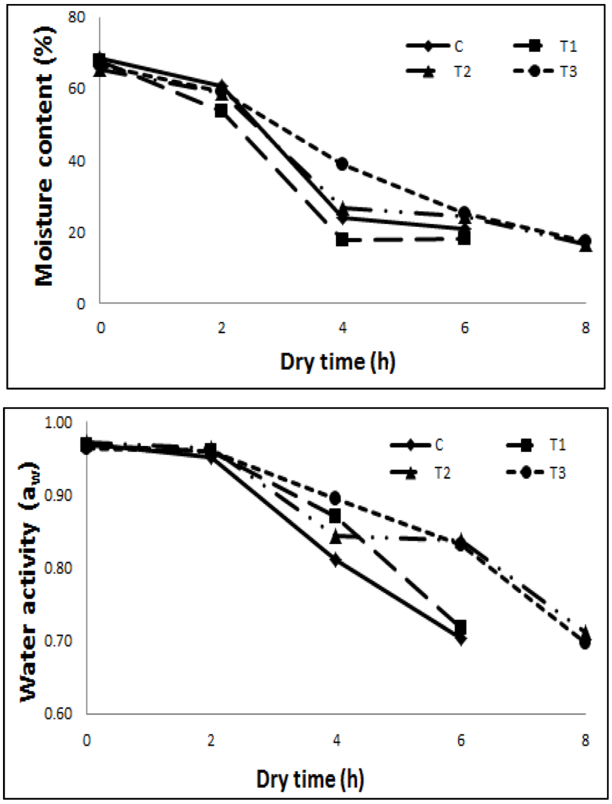

Fig. 1. Changes in moisture content and water activity of beef jerky during 21 d of storage at 25°C. Control: salt marinated; T1: replacement of salt with soy sauce; T2: replacement of salt with red pepper paste; T3: replacement of salt with soybean paste.

of samples, which were cured in salt solutions decreased more rapidly. During the salting process, the muscle absorbs the salt and loses water, and salting and dehydration results in decreased a_w (Thorarinsdottir *et al.,* 2001).

The moisture content for all beef jerky samples significantly decreased as drying proceeded up to 8 h (p<0.05). The moisture content varied from 68.72 to 16.48% depending upon the drying time and temperature of processing. The moisture content of beef jerky decreased rapidly for 2 and 4 h, respectively, while beef jerky decreased continuously during drying for 8 h (p<0.05). The ultimate moisture content of control and T1 samples after 6 h of drying was satisfied being 20.64% and 18.13%, respectively. Also, the ultimate moisture content of T2 and T3 samples after 8 h of drying was satisfied being 16.48% and 17.29%. As could be expected, an increase in the drying time made dehydration more intense, reaching lower values of moisture content.

pH, lightness and shear force

The changes in pH, lightness, and shear force of beef jerky during storage at 25°C were presented in Table 1. Significant changes in pH values occurred over 21 d (p< 0.05). The pH values of jerky generally range from 5.60 to 5.82. The samples with salt replacement showed a lower pH than the control (p<0.05). The pH for all samples significantly decreased as during storage days (p< 0.05). According to Leistner (1987), spoilage of various dried meat products by mold growth can be inhibited or delayed by lowering pH. Han *et al.* (2011) reported that beef jerky samples containing the soy sauce solution had a significantly lower pH value than the salt solution. The pH of Korean traditional soy sauce (kanjang) and commercial soy sauce ranged from 4.92-5.12 and 4.51-4.66 respectively (Lee *et al.,* 1997).

Table 1. pH, surface color (CIE L*) and shear force of beef jerky containing various salt substitutes

	Treatment[1)]	Storage (d)			
		0	7	14	21
pH	C	5.82±0.01^{Aa}	5.82±0.02^{Aa}	5.79±0.02^{Ba}	5.79±0.00^{Ba}
	T1	5.66±0.02^{Ab}	5.66±0.01^{Ac}	5.64±0.02^{Ab}	5.60±0.01^{Bb}
	T2	5.63±0.01^{Bbc}	5.71±0.02^{Ab}	5.60±0.01^{Cc}	5.61±0.01^{Cb}
	T3	5.61±0.02^{Cc}	5.69±0.01^{Ab}	5.66±0.01^{ABb}	5.63±0.03^{BCb}
Lightness (L^*)	C	24.43±0.59^{Ba}	23.81±0.50^{Ca}	24.07±0.17^{BCa}	25.02±0.02^{Aa}
	T1	23.56±0.60^{b}	23.51±0.23^{a}	23.83±0.95^{a}	23.56±0.04^{b}
	T2	21.70±0.26^{Cc}	21.53±0.25^{Cb}	23.17±0.00^{Ab}	22.70±0.53^{Bc}
	T3	22.98±0.18^{Ab}	21.41±0.61^{Bb}	20.48±0.02^{Cc}	20.31±0.04^{Cd}
Shear force (kg/cm^2)	C	6.76±1.32^{B}	7.10±0.12^{B}	7.92±0.14^{Bd}	9.10±0.29^{A}
	T1	6.66±0.18^{C}	7.33±0.55^{B}	8.59±0.04^{Ac}	9.12±0.40^{A}
	T2	7.43±0.35^{C}	8.53±0.12^{B}	9.75±0.07^{Aa}	10.02±0.11^{A}
	T3	7.71±0.31^{C}	8.16±0.61^{BC}	8.95±0.36^{Bb}	10.13±0.42^{A}

Data are means±standard deviation (n=3).

[1)]Control: salt marinated; T1: replacement of salt with soy sauce; T2: replacement of salt with red pepper paste; T3: replacement of salt with soybean paste.

[A,B,C]Means within a row with different superscript letters are significantly different at p<0.05.

[a,b,c]Means within a column with different superscript letters are significantly different at p<0.05.

Color results indicated that the lightness value was significantly higher in the control than the treatments beef jerky groups ($p<0.05$). The lightness value was significantly lower in the added soybean paste of beef jerky than all treatments ($p<0.05$). Color and appearance are major factors in consumer purchase decisions because they are presumed to be indicators of meat quality (Brewer *et al.,* 2002). The replacement of salt with soy sauce solutions changed the color attributes of the beef jerky by decreasing lightness.

One of the most important attributes of jerky is the hardness that can be measured as shear force. Yang (2000) managed to make semi-dried beef jerky with higher moisture content (a_w 0.85) and improved textural property. The shear force values of the samples varied from 6.76 to 10.43 (kg/cm^2) ours the processing combinations. According to Han *et al.* (2011), beef jerky samples containing the soy sauce solution had a significantly lower shear force than samples prepared with the salt solution. However, our results showed that the shear force value was increased dramatically with increasing storage days ($p<0.05$). Of the treated samples, control and T1 samples had slightly lower shear force values than those of T2 and T3 samples. Also, shear force value was lower in the salt solution of the final beef jerky compared to all treatment groups of beef jerky at 14 d storage ($p<0.05$). It was clear that the elevation of shear force through increased drying time was due to decreasing moisture content and that decrease in shear force by curing in salt solutions was related to an increase in the water holding capacities of jerky samples by the addition of salt.

Microbiological analysis

Changes in total plate counts of beef jerky during storage is shown in Fig. 2. The total plate counts for all treatments increased with storage days ($p<0.05$). The total plate counts was significantly lower in control than other jerky samples until 14 d of storage, whereas the total plate counts of T1 was significantly lower than the control at 21 d of storage ($p<0.05$). The low microbial levels in control and T1 samples seem to be due to its low moisture content and a_w (Gould and Christian, 1988; Hocking, 1988). Hurdles to microbial survival and growth include drying temperature, low a_w (<0.85), and preservatives such as salt and organic acids depending on the composition of the marinate mixture (Gailani and Fung, 1986; Quinton *et al.,* 1997). In this study, the a_w values for control and T1 samples rapidly decreased during drying time. This indicates that beef jerky with salt and soy sauce, in comparison to beef jerky with red pepper paste and soybean paste under the same drying conditions, may be safe from microbial growth due to a reduction of a_w.

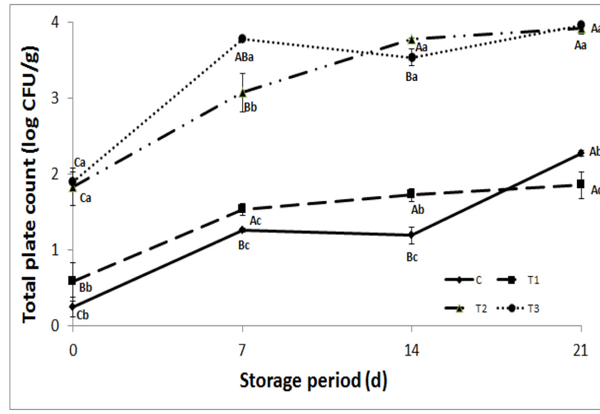

Fig. 2. Changes in total plate count (Log CFU/g) of beef jerky during 21 d of storage at 25°C. Control: salt marinated; T1: replacement of salt with soy sauce; T2: replacement of salt with red pepper paste; T3: replacement of salt with soybean paste. Different capital letters indicate significant differences within storage days ($p<0.05$). Different small letters indicate significant differences within each jerky samples ($p<0.05$).

Thiobarbituric acid reactive substance (TBARS) values

The TBARS value is the most common indicator used to measure the degree of lipid oxidation in meat products (Obanu, 1988). The TBARS values of beef jerky samples were gathered to investigate the effect of the addition of salt, soy sauce, red pepper paste, and soybean paste on lipid oxidation during 21 d of storage (Fig. 3). Day 0 storage, beef jerky containing red pepper paste and soybean paste were significantly lower than those for the other treatments ($p<0.05$). In this study, the TBARS values of beef jerky samples red pepper paste and soybean paste with ranged from 2.94-3.19. Yang *et al.* (2009) reported that the initial TBA value of beef jerky is 2.96 mg/kg, as in this study. Also, the TBARS for all treatments increased with storage days ($p<0.05$). The sample with soy sauce replacement showed a significantly higher TBARS value than other jerky samples, while the sample with soybean paste replacement showed the lowest TBARS value among the jerky samples after 21 d of storage ($p<0.05$). As a_w value decreases there was a proportional increase of lipid oxidation (Chen *et al.*, 2002). These findings agree with Ockerman (1983) who found that the increased TBA values in meat products were responsible for the increased salt concentration. Also, Jin *et al.* (2005) reported that the TBARS values of fermented pork increase significantly

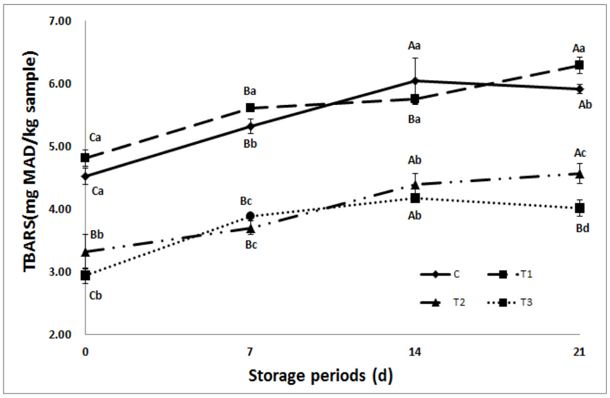

Fig. 3. Changes in TBARS (mg MAD/kg sample) of beef jerky during 21 d of storage at 25°C. Control: salt marinated; T1: replacement of salt with soy sauce; T2: replacement of salt with red pepper paste; T3: replacement of salt with soybean paste. Different capital letters indicate significant differences within storage days (p<0.05). Different small letters indicate significant differences within each jerky samples (p<0.05).

during storage and the TBARS value of fermented pork with soybean paste was lower compared to the soy sauce seasoning. Moon *et al.* (2002) demonstrated that melanoidin, which is formed from the Maillard reaction, is the major factor dictating the antioxidant activity of soy sauce. Soybean paste contained large amounts of isoflavone aglucons and phenolic acids (Chung *et al.,* 2011). *Gochujang* possesses various biological activities, including anti-obesity (Ahn *et al.,* 2006), anti-mutagenic (Choo, 2000), and anti-cancer (Kim *et al.,* 2005).

Sensory evaluation

The sensory panels were convened to assess the effects on the color, off-flavor, saltiness, texture and overall acceptability of beef jerky samples (Table 2). The most important sensory attributes of jerky are texture, color and flavor, which are determined by the raw material and numerous technological factors (Albright *et al.,* 2000). Also, Lee and Kang (2003) indicated that the texture of jerky-type snack foods is one of the most important sensory attributes, determining the uniqueness and market attractiveness of products. The color scores of replacing salt with red pepper paste and soybean paste beef jerky were higher than the control sample (p<0.05). Off-flavor of beef jerky ranged from 2.38 to 3.25, and there was no significant difference among the beef jerky samples. Sensory results indicated that the saltiness intensity was significantly (p<0.05) higher in the control than the beef jerky treatment groups. Further, texture and overall acceptability scores were improved by replacing salt with soy sauce. The overall acceptability scores ranged from 4.86 to 6.50, with maximum acceptability obtained from the beef jerky sample, which replaced salt with soy sauce (p<0.05). This may be due to better texture characteristics. Tenderness is the main factor which contributes to the overall eating quality of meat (Mori *et al.,* 2001). The jerky's texture can be altered by the moisture content, as is done for other intermediate moisture meats (Farouk and Swan, 1999). Therefore, it is suggested that the replacing salt with soy sauce in regards to beef jerky could be used to increase the texture and overall acceptability of meat products, providing the consumer with food containing soy sauce.

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Table 2. Sensory evaluation of beef jerky containing various salt substitutes

	Treatments[1)]			
	C	T1	T2	T3
Color	4.10 ± 0.88^{C}	4.75 ± 1.49^{BC}	5.57 ± 1.40^{AB}	6.30 ± 1.06^{A}
Off-flavor	2.83 ± 0.41	3.25 ± 0.50	2.43 ± 0.98	2.38 ± 0.74
Saltiness	6.63 ± 0.74^{A}	4.13 ± 0.99^{B}	5.00 ± 1.15^{B}	5.00 ± 1.00^{B}
Texture	5.44 ± 1.01^{AB}	5.75 ± 1.04^{A}	4.71 ± 0.76^{B}	5.67 ± 0.87^{AB}
Overall acceptability	5.17 ± 0.41^{BC}	6.50 ± 0.58^{A}	5.75 ± 0.50^{B}	4.86 ± 0.38^{C}

Data are means±standard deviation (n=8).

[1)]Control: salt marinated; T1: replacement of salt with soy sauce; T2: replacement of salt with red pepper paste; T3: replacement of salt with soybean paste.

^{A,B,C}Means within a row with different superscript letters are significantly different at p<0.05.

Based on a 9-point intensity scale (1=dislike extremely or extremely light/bland/tough; and 9=like extremely or extremely dark/intense/tender).

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