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ARTICLE

Physicochemical Characteristics of Beef Jerky Cured with Salted-fermented Anchovy and Shrimp

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Abstract

The aim of this study is to evaluate the availability of salted and fermented fish (SFF) including salted and fermented anchovy (SFA) and shrimp (SFS) as a marinade of beef jerky. In curing solutions, half (SFA 1 and SFS 1) or whole (SFA 2 and SFS 2) salt-water was replaced with SFF juices. Higher water activity (a_w) was found in the beef jerky cured with SFFs than the control (C) ($p<0.05$). The SFFs had the effect of causing a decrease in hardness and an increase in cohesiveness ($p<0.05$). Among the treatment samples, springiness was the highest in SFA2 and SFS2 ($p<0.05$) and the lowest values of Warner-Bratzler shear force were found in SFA1 and SFA2 ($p<0.05$). The SFFs also had the effect of increasing the flavor of the sensory properties; however, color measurements from both the instrumental surface color (L*, a*, b*, chroma, and hue angle) and color of sensory evaluation were decreased by addition of SFFs ($p<0.05$). Therefore, we conclude the SFFs can improve the texture and sensory properties of the beef jerky. In particular, the SFS is a good ingredient for the curing solution. However, studies are still needed on improving the a_w, pH, and surface color of the beef jerky to apply the SFFs for making beef jerky.

Key words: beef jerky, salted-fermented fish, anchovy, shrimp

Introduction

Jerky is one of the oldest meat products and has been sold for many years in the form of snack foods. Jerky is obtained from sliced whole muscles marinated and dried. Jerky type products are characterized by a diversity of raw materials, spices, and other additives, and by the technological procedures such as curing, smoking, drying, and packaging (Konieczny *et al*., 2007). With growing and varying consumer preferences for high quality foods with good texture, color, flavor, and nutritional value, few attempts have been made to assess the quality of jerky using various processing techniques such as the marination method, the drying condition, and the raw meat conditions (Albright *et al*., 2003; Calicioglu *et al*., 2003; Choi *et al*., 2006; Han *et al*., 2007; Konieczny *et al*., 2007; Yang *et al*., 2009). As snack foods, the sensory qualities including texture, color, and flavor are considered to be the most important attributes of jerky (Konieczny *et al*., 2007).To improve the qualities of jerky, we introduced the juice of salted and fermented fish (SFF) as the marinade.

The SFF products are popular in South-East Asian countries, such as Korea (Jeotgal), Thailand (Som-fak), China (Suan yu), and Japan (fish nukazuke) (Adams *et al*., 1985; Ishige, 1993; Kuda *et al*., 2012; Mah *et al*, 2002; Zeng *et al*., 2013). The SFFs are produced by mixing whole fish with 5-20% of salt for several months at the ambient temperature. The fish fermentation process consists of the transformation of organic substances into simpler compounds such as amino acids, peptides and various nitrogenous compounds (Peralta *et al*., 2008). SFFs

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and their liquid sauce have been widely utilized in a variety of processed products due to their salty, unique flavor and aroma (Peralta *et al*., 2008; Tsai *et al*., 2006). For dried food such as jerky to be shelf stable, low water activity (a_w<0.85) and preservatives including salt, organic acids and sodium nitrite are required (Gailani and Fung, 1986). SFF juice contains salt as well as various flavor and aroma compounds.

For these reasons, the beef jerky was prepared by curing with the SFF juice made of anchovy and shrimp, and the quality properties of beef jerky were investigated. The aim of this study is to evaluate the availability of SFF juice as a marinade of beef jerky.

Materials and Methods

SFF preparation

Salted and fermented anchovy (SFA) and shrimp (SFS) were purchased at a local retail store in Jinju, Korea on August 2012. Anchovy and shrimp were washed thoroughly and mixed with salt at a ratio of 20% to raw fish. The mixtures were piled in glass containers and the containers were capped. They were then fermented at room temperature (15-25°C) for three months. The juices naturally released from SFFs were collected and filtered using a cheese cloth. After filtering, the salinity of the SFF juice was measured using aconductivity meter (CR-30R, TOA-DKK, Japan) and adjusted to 11.5% salt using distilled water.

Preparation of beef jerky

A total of five bovine *semimembranosus* (BS) muscles (10 kg) were obtained from cattle (Hanwoo, Korean native cattle) at a commercial slaughterhouse. The BS muscles were dissected from each carcass within 48 h of postmortem, and their subcutaneous fat and visible connective tissue were removed. The BS muscles were sliced to 0.5-cm thick slices using a meat slicer (HFS 350G, Hankook Fujee Industries Co., Ltd., Korea) and cut into pieces of 5.0 ×10.0×0.5 cm. All BS slices were divided randomly into five groups (C, SFA1, SFA2, SFS1, and SFS2) and cured with different curing solutions in a cold room (4°C) for 24 h. Curing solutions for C consisted of 3.0% sugar, 3.9% starch syrup, 0.2% black pepper, 0.024% sodium nitrite, and 9.0% salt-water (based on raw meat weight). The salt-water was prepared by dissolving sodium chloride in distilled water and its salinity adjusted to 11.5% salt as the same salinity of SFF juice.The curing solutions for treatments were prepared by replacement of half or whole of salt-water by SFA or SFS juice. The formulation of cure solution is presented in Table 1.

The cured BS muscles were dried in a dryer (DS80-1, Dasol Scientific Co. Ltd., Korea) at 70°C for 6 h to achieve a water activity of 0.83. After drying, the beef jerky samples were cooled at the ambient temperature.

Water activity (a_w) and pH

The water activity was determined using a water activity meter (AQX-2, Nagy mess system, Germany) calibrated at the ambient temperature (20°C) with distilled water (a_w=0.999) and saturated solution of NaCl (a_w=0.756) and KCl (a_w=0.853). The pH was analyzed on homogenates of 5.0 g sample in 45 ml of distilled water using a pH meter (Model 230, Mettler-Toledo GmbH, Switzerland).

Moisture and protein contents

The beef jerky samples were cut into small pieces using sharp scissors and samples were analyzed for moisture and protein contents. Moisture content was determined according to the AOAC method (AOAC, 2000). Protein content was analyzed by Kjeldahl procedure using a Kjeldahl nitrogen analyzer (Kjeltec® 2300 Analyzer Unit, Foss

Table 1. Formulation of the curing solution for making beef jerky

Ingredients	Treatments				
	C	SFA1	SFA2	SFS1	SFS2
Salt-water[1)]	9.0	4.5	-	4.5	-
SFA[2)]	-	4.5	9.0	-	-
SFS[3)]	-	-	-	4.5	9.0
Sugar	3.0	3.0	3.0	3.0	3.0
Starch syrup	2.5	2.5	2.5	2.5	2.5
Black pepper	0.2	0.2	0.2	0.2	0.2
Sodium nitrite	0.024	0.024	0.024	0.024	0.024
Total	14.724	14.724	14.724	14.724	14.724

[1)]The salt-water was prepared by dissolving sodium chloride in distilled water and adjusting its salinity to 11.5% salt.

[2,3)]The juices released naturally from the salted and fermented anchovy (SFA) or shrimp (SFS) and their salinities were adjusted to 11.5% salt.

Tecator AB, Höganas, Sweden).

Warner-Bratzler shear force (WBSF) and texture property analysis (TPA)

The samples were prepared as a uniform shape (1.0×2.0×0.3 cm) for measurements of WBSF and TPA. An Instron Universal Testing Machine (Model 4400, Instron Co., USA) was used for analysis of WBSF (N). Its cross-head speed was 200 mm/min and a 500 N load cell was applied. TPA including hardness (N), cohesiveness (%), and springiness (%) was determined using a Rheo-meter (Compac-100, Sun Scientific Co., Japan). Force-time deformation curves were obtained with mode #21 (Real), 200 N load cell, 2 mm/s table speed, Rep. 2, and adapter area 5 mm. Hardness, cohesiveness, and springiness were quantified as described by Bourne (1978).

Surface color

The surface color of the samples was measured, using a colorimeter (CR-300, Minolta Co., Japan) that was standardized with a white ceramic plate (Y=93.5, x= 0.3132, y=0.3198). Commission International d'Eclairage (CIE) L* (lightness), a* (redness),b* (yellowness), chroma ($(a^{*2}+b^{*2})^{1/2}$), and hue angle ($\tan^{1}(b^*/a^*)$) were observed.

Sensory evaluation

Sensory evaluation was performed by 12 panelists (5 females, 7 males, aged between 24 and 40 years) experienced in meat sensory evaluation. The panelists evaluated the beef jerky for color, flavor, odor, saltiness, tenderness and overall acceptability using a 9-point scale described by Meilgaard *et al*. (1999) as presented in Table 2. The panelists were seated in individual booths, and distilled water was used to cleanse the palate between the beef jerky samples (Keeton, 1983).

Statistical analysis

One-way analysis of variance (ANOVA) was used to evaluate the significance of differences of the obtained data, and Duncan's multiple range test was employed to determine the significance between treatments (SAS, 2002). All data are presented as means with standard deviation (SD) and a significance level of $p<0.05$ was used for statistical analysis of means from treatments.

Results and Discussion

a_w and pH

The results of a_w are presented in Table 3. The a_w of beef jerky was within the range of 0.77-0.81. There were significant differences in a_w among the treatments ($p<0.05$). The a_w of control jerky (C) was lower than those of other samples of beef jerky cured by SFA or SFS ($p<0.05$); however, there were no significant differences among the treatments except for C ($p>0.05$). Dried foods such as jerky are shelf-stable products stored at room temperature and consumed without additional cooking. Bacterial growth of jerky type products is primarily inhibited by lowering a_w (<0.85) (Gailani and Fung, 1986). In the present study, all beef jerky had low a_w (<0.80) and thus are stable for bacterial growth. However, SFF juices had the effect of increasing the a_w of beef jerky. According to the previous reports on salted-fermented fish, free amino acids, amines, peptides, and other nitrogenous compounds were produced by fermentation of fish regardless of fish type and salt content (Cho *et al*., 1999, 2000; Mohamed *et al*., 2009; Peralta *et al*., 2008; Roseiro *et al*., 2008). Therefore, it is assumed that the relatively higher a_w for SFF juice-treated beef jerky was caused by the various compounds of the

Table 2. Definitions and scale of sensory attributes evaluated

Attribute	Definition
Color 1=Extremely light 9=Extremely dark	Evaluate the intensity of the gray color
Flavor 1=Extremely weak 9=Extremely strong	The combination of taste and tactile stimuli perceived while chewing and swallowing
Odor 1=Extremely weak 9=Extremely strong	Intensity of overall odor
Saltiness 1=No salty taste 9=Extremely salty	Taste associated with sodium ions
Tenderness 1=Extremely tough 9=Extremely tender	Minimum force required to cut or chew the beef jerky sample
Overall acceptability 1=Extremely undesirable 9=Extremely desirable	The impression of preference for the beef jerky considering the overall sensory attributes evaluated

Table 3. Water activity (a_w) and pH of beef jerky cured with salted and fermented anchovy and shrimp

Treatments[1)]	a_w	pH
C	0.77±0.01[b]	5.72±0.01[c]
SFA1	0.80±0.01[a]	5.73±0.01[c]
SFA2	0.80±0.01[a]	5.75±0.01[b]
SFS1	0.81±0.01[a]	5.79±0.02[a]
SFS2	0.81±0.01[a]	5.79±0.01[a]

[a-c]Means±SD with different superscripts in the same column are significantly different ($p<0.05$).
[1)]Treatments are the same as Table 1.

SFF juice, such as amino acids, peptides, organic acids, and amines.

The pH values of beef jerky showed significant differences between treatments ($p<0.05$) (Table 3). C and SFA1 had the lowest pH, while SFS1 and SFS2 hadthe highest pH values among the treatments ($p<0.05$). As mentioned by Leistner (1987) and Ogahara *et al*. (1995), low pH can inhibit or delay the spoilage of various dried meat products by mold and microorganism growth. In the present study, the higher pH values of jerky cured by SFF juices are a result of the pH values of raw SFF juices. The pH of SFA and SFS juices were 5.51±0.02 and 5.72±0.01, respectively (not presented). From a shelf-stable point of view, some improvements in the salinity of the curing solution or in the processing condition such as drying time and temperature are needed.

Moisture and protein contents

Among the treatments, SFS1 and SFS2 were the highest in moisture content but the lowest in protein content ($p<0.05$), as shown in Table 4. SFA1 and SFA2, on the other hand, had lower moisture content and higher protein content than the other treatments ($p<0.05$). The moisture and protein contents of beef jerky were within the range of 23.52-27.04% and 64.41-67.56%, respectively. a_w is closely related to moisture content in meat products, so it is important to control the moisture content (Leistner, 1987). In the present study, beef jerky cured by SFS juice, regardless of SFS juice level, had higher moisture content and $a_w$than C, SFA1, and SFA2. However, C had the lowest a_w among the treatments, but its moisture content was not lower than those of SFA1 and SFA2. Although the salinity is the same between salt-water and SFF juices, in the making of beef jerky, the a_w as well as moisture content of other components that consist of SFF juices could be affected.Moreover, SFF juice has nitrogenous compounds as well as various microorganisms (Jung *et al*., 2005; Mah *et al*., 2008; Park *et al*., 2010). Microorganisms and their products may be affected moisture content and a_w, additional researches are needed.

The moisture-to-protein ratio (MPR) value in raw beef is on average 4.5, but for purposes of microbial safety, that in jerky type productscannot exceed 0.75 (USDA, 1996). MPR ranged from 0.35 to 0.42, as shown in Table 4. Jerky-type snack foods are classified as intermediate-moisture foods, which exhibit proteincontent of 50%, a low fat content (approximately 3.6%), relatively high salt content (approximately 6.0%), a low water content (20-25%), and a_w below 0.8 (Chen *et al*., 2002; Konieczny *et al*., 2007; Labuza *et al*., 1970). The beef jerky cured with SFFs presented low moisture content (23.52-27.04%) and 64.41-66.83% of protein content, thus they exhibited low MPR values below 0.75.

WBSF and TPA

The results of WBSF and TPA, including hardness, cohesiveness, and springiness, are presented in Table 5. The beef jerky cured with SFS showed lower WBSF than C

Table 4. Moisture, protein content, and moisture-to-protein ratio of beef jerky cured with salted and fermented anchovy and shrimp

Treatments[1)]	Moisture content (%)	Protein content (%)	Moisture-to-protein ratio (MPR)
C	25.32±0.31^{b}	66.22±0.42^{b}	0.38
SFA1	23.52±0.26^{c}	66.83±0.31^{ab}	0.35
SFA2	23.77±0.17^{c}	67.56±0.49^{a}	0.35
SFS1	26.71±0.41^{a}	64.57±0.54^{c}	0.41
SFS2	27.04±0.35^{a}	64.41±0.55^{c}	0.42

$^{a-c}$Means±SD with different superscripts in the same column are significantly different ($p<0.05$).
[1)]Treatments are the same as Table 1.

Table 5. Warner-Bratzler shear force (WBSF), hardness, cohesiveness, and springiness of beef jerky cured with salted and fermented anchovy and shrimp

Treatments[1)]	WBSF	Hardness (N)	Cohesiveness (%)	Springiness (%)
C	84.48±1.47^{a}	100.85±4.97^{a}	16.78±1.30^{d}	80.30±1.67^{b}
SFA1	83.79±3.43^{a}	82.52±2.50^{c}	26.24±1.59^{a}	57.25±2.25^{b}
SFA2	83.69±1.08^{a}	89.62±2.42^{b}	21.67±0.83^{c}	72.96±6.82^{a}
SFS1	65.56±2.45^{b}	82.09±1.32^{cd}	23.92±1.05^{b}	53.24±2.43^{b}
SFS2	68.01±5.44^{b}	77.92±2.36^{d}	22.57±1.57^{bc}	77.26±2.19^{a}

$^{a-d}$Means±SD with different superscripts in the same column are significantly different ($p<0.05$).
[1)]Treatments are the same as Table 1.

(p<0.05), whereas the beef jerky cured with SFA did not exhibit any significant difference from C (p>0.05). Among the treatments, C had the highest value of hardness (p< 0.05); however, other TPAs such as cohesiveness and springiness were lowest in C (p<0.05). SFS1 and SFS2 had the lowest hardness as the result of WBSF (p<0.05). These results agree with the previous report that WBSF or hardness is affected by moisture content (Yang *et al*., 2012). It is considered that various compounds which resulted from the fermentation of fish (Cho *et al*., 1999, 2000; Mohamed *et al*., 2009; Peralta *et al*., 2008; Roseiro *et al*., 2008) also affected WBSF and TPA of beef jerky. In the results of cohesiveness and springiness, totalreplacement of salt-water with SFA had the effect of causing a decrease in the cohesiveness of beef jerky, but an increase in springiness. The same effect of SFS was also found in the springiness of SPS1 and SPS2, but not in cohesiveness. Therefore, curing with SFS could decrease the WBSF of the beef jerky, and both SFA and SFS are effective for improving the TPA of the beef jerky regardless the level of SFFs. Furthermore, total replacement with SFFs could affect the increase in springiness of the beef jerky.

Surface color

The results for surface color of the beef jerky are shown in Table 6. As expected, C had the highest values of all surface color traits (p<0.05) and only SFA1 did not show significant differences in lightness (L*), and hue angle with C (p>0.05). SFA decreased the redness (a*), yellowness (b*) and chroma of beef jerky according to the level of replacement (C>SFA1>SFA2). However, there were no significant differences in all color measurements except for L* between SFS1 and SFS2 (p>0.05). Other studies have reported that L*, a*, and b* of general beef jerky exhibited the range of 22.85-31.12, 10.2-11.96, and 4.52-10.8, respectively (Konieczny *et al*., 2007; Sindelar *et al*., 2010; Yang *et al*., 2009). According to Konieczny *et al*. (2007), surface color values of beef jerky can change according to the drying time at the same temperature, i.e., Hunter L-value decreased and a-value increased with increase of drying time from 0 to 7 h. However, in the present study, because the same drying conditions, such as temperature (70°C) and time (6 h), were applied to the treatments, the effect of color change was caused by SFFs. The brown color intensity of salt-fermented shrimp pastes increased with increase of the fermentation period (Peralta *et al*., 2008). In the present study, SFFs caused a steep decrease in the surface color values, especially a*, b*, and chroma. Those samples of the beef jerky replaced with 50% SFS (SFS1) and 100% SFS (SFS2) and SFA (SFA2) decreased to be less than half of a*, b*, and chroma of C.

Sensory evaluation

As presented in Table 7, color, flavor, saltiness and overall acceptability were significantly different between treatments in sensory evaluation (p<0.05). The color of

Table 6. Surface color of beef jerky cured with salted and fermented anchovy and shrimp

Traits	Treatments[1)]				
	C	SFA1	SFA2	SFS1	SFS2
Lightness (L*)	25.21±0.67^a	24.41±0.30^{ab}	23.81±0.37^b	23.37±0.35^b	20.82±0.30^c
Redness (a*)	9.72±0.44^a	7.99±0.73^b	4.77±0.13^c	4.42±0.39^c	4.52±0.26^c
Yellowness (b*)	2.55±0.22^a	1.76±0.35^b	1.15±0.05^c	0.88±0.11^{cd}	0.77±0.01^d
Chroma	10.04±0.48^a	8.17±0.78^b	4.90±0.12^c	4.50±0.4^c	4.58±0.26^c
Hue	14.60±0.62^a	12.27±1.44^{ab}	13.43±0.93^{bc}	11.13±0.38^{cd}	9.60±0.44^c

$^{a-d}$Means±SD with different superscripts in the same row are significantly different (p<0.05).
[1)]Treatments are the same as Table 1.

Table 7. Sensory evaluation of beef jerky cured with salted and fermented anchovy and shrimp

Traits	Treatments[1)]				
	C	SFA1	SFA2	SFS1	SFS2
Color	4.33±0.52^b	4.40±0.89^b	5.80±0.45^a	5.83±0.41^a	6.50±0.55^a
Flavor	4.17±0.98^c	5.50±0.55^{ab}	5.50±1.00^{ab}	5.40±0.55^{ab}	6.00±0.82^a
Odor	1.03±0.18	1.10±0.15	1.17±0.16	1.20±0.18	1.22±0.14
Saltiness	6.25±0.50^a	6.33±0.52^a	5.20±0.45^b	5.17±0.41^b	5.40±0.55^b
Tenderness	5.45±0.56	5.53±0.41	5.75±0.56	5.98±0.50	5.82±0.36
Overall acceptability	5.38±0.23^{bc}	5.20±0.30^c	5.75±0.42^{ab}	5.50±0.25^b	6.05±0.35^a

$^{a-c}$Means±SD with different superscripts in the same row are significantly different (p<0.05).
[1)]Treatments are the same as Table 1.

beef jerky showed a similar trend with the result of surface color (instrumental analysis). Curing with SFA and SFS brought about decreases in all surface color measurements as shown in Table 7. In the result of sensory evaluation, the beef jerky cured with 50% of SFS (SFS1) and 100% SFA (SFA2) and SFS (SFS2) was darker than C ($p<0.05$). Flavor values for treatments cured with SFFs were significantly higher than that for C ($p<0.05$). The SFFs contain various compounds, such as amino acids, peptides, and nitrogenous substance, because the fish fermentation process induces the transformation of organic substances to various simpler compounds, which are the origins of their unique flavors and aromas (Peralta *et al*., 2008; Tsai *et al*., 2006). In the present study, these unique flavors and aromas from SFFs played a positive role in the sensory properties of the beef jerky. Saltiness was higher in C and SFA1 than in SFA2, SFS1, and SFS2 ($p<0.05$). Salt is a major ingredient for the food industry and it helps to enhance the flavor intensity of foods (Batenburg and van der Velden, 2011; Wirth, 1989). Among the various amino acids, it is known that arginine is a good contributor to the salty taste (Breslin and Beauchamp, 1997; Ogawa *et al*., 2004). In the present study, the various compounds from SFFs enhanced the flavor of the beef jerky; however, they had the effect of reducing the saltiness of the beef jerky. Among the treatments,overall acceptability was the highest in SFS2 ($p<0.05$), whereas SFA1 showed the lowest overall acceptability ($p<0.05$) because of low color and high saltiness values.

Conclusions

The SFFs improved the texture and sensory properties of the beef jerky, but negative effects were found in a_w, pH, and surface color. The compounds from SFFs could be good enhancers for the flavor of the beef jerky. Overall, the beef jerky cured with 100% SFS exhibited good WBSF, TPA, and sensory properties. However, studies are still needed on improving the a_w, pH, and surface color of the beef jerky to apply the SFFs for making beef jerky.

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