Effects of swelled pig skin with various natural vinegars on quality characteristics of traditional Korean blood sausages (*Sundae*)

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Abstract This study evaluated effects of swelled pig skin (SPS) with various natural vinegars (*Bokbunja*, brown rice, cider, and lemon vinegars) on the quality of the Korean traditional blood sausages. Adding SPS with various natural vinegars resulted in increased moisture content, cooking loss, L* values, and a* values and decreases in fat, protein content ($p < 0.05$), hardness and thiobarbituric acid-reactive substance values in the meat product samples compared to those in the control. Treatments containing SPS with various natural vinegars decreased the warmed-over flavor but increased the tenderness. These results indicate that SPS with various natural vinegars would improve the quality characteristics and inhibit lipid oxidation of traditional Korean blood sausages.

Keywords: vinegar, meat product, quality characteristic, functional property

Introduction

Traditional Korean blood sausage (*Sundae*) is made with lean meat, vegetables, pork blood, and various seasonings and spices such as onion, garlic, ginger, and black pepper (1). The cooked lean meat and vegetables are generally ground and then meat stock, and various additives are added and mixed. The mixture is stuffed in hog casings, and the product is boiled for 50–60 min at 80–85°C. It is similar in ingredients and nutrition to the blood sausages of Europe. Currently, traditional Korean blood sausage is made with various functional materials, include natural antioxidants and gelatin.

Pig skin consists of 44.24% moisture, 28.29% fat, 26.47% protein, and about 260 mg/g collagen (2). Pig skin must be pretreated with acid or base to convert the insoluble collagen into soluble collagen, and the gelatin is then extracted by heating in hot water at above 45°C (3). The physico-chemical properties of gelatin are affected by pretreatment with acid or base, the extraction temperature, and time. Swelling of pig skin by acid or base solution can result in a softer texture than raw pig skin because swollen gelatin closely interacts with water (4). Osburn *et al.* (5) studied that addition of pig skin connective tissue resulted in softer texture on bologna. Gelatin has been used as a binder, extender, stabilizer, gelling agent, and emulsifier in the food industry (4).

Vinegar has been used as a traditional fermented condiment all over the world (6). Acidic vinegar has functional properties such as

improved digestion and appetite, prevention of obesity, hypertension, diabetes, aging, and hematosi s by peroxide decomposition, and it inhibits food spoilage (7). Natural vinegars made from various grains and fruits are preferred by consumers (8). Different types of natural vinegars, such as brown rice, *Bokbunja*, cider, lemon, persimmon, pomegranate vinegars, are grown in Korea for consumption (6). Brown rice contains more than three times the dietary fiber and about 70% unsaturated fatty acids and functional components (9). Apple contains carbohydrates, acids, nitrogen compounds, polyphenols, minerals, and vitamins (10). Lemon (*Citrus limon* (L.) Burm. F) contains several important nutrients such as flavonoids, citric acid, vitamin C, and minerals and has antioxidant and anti-inflammatory activities (11). There is a study that spraying of cider vinegar improved quality properties of pork (12). *Bokbunja* (*Rubus coreanus* Miquel) contains bioactive phytochemicals, including phenolic acids, organic acids, flavonoids, and gallotannin (13). Previous studies have shown that brown rice, apple, lemon, and *bokbunja* contain various organic acids and physiological active substances that help inhibit food spoilage (9–11,14).

The aim of this study was to evaluate the effect of swelled pig skin (SPS) and various vinegars, have preference by consumers and amount of bioactive substances, on the quality characteristics including chemical composition, swelling yield, pH values, cooking loss, TBARS, color, texture, and sensory evaluation of traditional Korean blood sausages.

Fig. 1. The diagram of Korean blood sausage containing swelled pig skin (SPS) with various natural vinegars.

Materials and Methods

Formulation and processing of blood sausages Fresh pork meat (*M. biceps femoris*, *M. semitendinosus*, and *M. seimembranosus* muscle) were purchased from a pilot plant at local market, Korea 48 h postmortem. All subcutaneous and intramuscular fat and visible connective tissue were removed from the fresh ham muscles. Pig skin and blood were also collected from the slaughter house. The epidermis and dermis (inner skin and outer skin) of pig skin were used. For each batch (5 kg), preparation process of blood sausages was presented in Fig. 1. Total of three replicates of blood sausage processing (3 batches) was conducted.

Pig skin pre-treatment: 20% pig skin was soaked in various natural vinegars (*Bokbunja*, brown rice, cider, and lemon vinegar) in ratio 2:3 (pig skin:vinegar) at a controlled pH of 2.80 ± 0.01 for 24 h and then washed in distilled water until the wash water had above pH 6. Commercial *bokbunja* vinegar (Chungjungone, Seoul, Korea; pH

2.71), brown rice vinegar (Ottogi, Anyang, Korea; pH 2.62), cider vinegar (Beksul, Incheon, Korea; pH 2.79), and lemon vinegar (Beksul; pH 2.65) were purchased from a local market. The SPS was preheated to 80°C for gelatin extraction during 30 min (center temperature of cooked SPS: $75 \pm 1^\circ\text{C}$) and then ground through a 3 mm plate. The pig skin of the control sample did not undergo the swelling process.

The SPS and lean meat were mixed using the following process. The formulation included 65% lean pork meat, 20% preheated SPS, 5% pork back fat, 5% pork blood, 5% meat stock, 2% isolated soy protein (ISP), 1.5% nitrite pickle salt (NPS), 0.5% sugar, 1% monosodium L-glutamate (MSG), 2.5% onion, 2% garlic, 0.3% ginger, and 0.2% black pepper. The addition amounts of preheated SPS based on weight before swelling. The lean pork meat, boiled fat (70°C, 30 min) and pork blood were ground through a 3 mm plate, and then the preheated SPS, extracted gelatin, meat stock, ISP, NPS, sugar, MSG, onion, garlic, ginger, and black pepper were added. This mixture was

stuffed into hog casings (approximate diameter of 30 mm) using a stuffer (IS-8; Sirman, Marsango, Italy). The percentages were based on the control formula weight. The blood sausages were then cooked in a smoker (MAXI 3501; Kerres, Backnang, Germany) at 80°C for 50 min, cooled at room temperature for 1 h and stored at 4°C prior to analysis.

Chemical composition The chemical properties of the samples were determined using standard (15). The moisture content was determined based on the weight loss after 12 h of drying at 105°C in a drying oven (SW-90D; Sang Woo Scientific Co., Bucheon, Korea). Fat content was determined by the Soxhlet method with a solvent extraction system (Soxtec Avanti 2050 Auto System; Foss Tecator AB, Höganäs, Sweden). The protein content was determined by the Kjeldahl method with an automatic Kjeldahl nitrogen analyzer (Kjeltec 2300 Analyzer Unit; Foss), and ash content was determined according to the AOAC (15).

Swelling yield Pig skin was weighed (500 g) and soaked in various natural vinegars at a controlled pH of 2.8, for 24 h and then rinsed until the wash water had a neutral pH. The percentage swelling yield was calculated from the weights after straining the rinsed pig skin through a sieve for 10 min and weighing.

pH values The pH values of the samples were determined using a pH meter (Model 340; Mettler-Toledo GmbH, Schwerzenbach, Switzerland). The pH of the blood sausages was measured after blending 5 g of sample with 20 mL of distilled water for 60 s in a homogenizer (Ultra-Turrax SK15; Janke & Kunkel, Staufen, Germany).

Cooking loss The meat mixture was weighed (80 g) and stuffed into hog casings and then heat processed at 80±1°C for 50 min. After cooling for 30 min, the cooked blood sausages were weighed and the percentage cooking loss was calculated from the weights.

Cooking loss (%) =

$$\frac{[(\text{weight of sausage before cooking} - \text{weight of sausage after cooking}) / \text{weight of sausage before cooking}] \times 100}{}$$

Color measurement Color measurements were taken using a colorimeter (Chroma meter CR-210; Minolta, Tokyo, Japan; illuminate C), calibrated with a white standard plate CIE $L^* = 97.83$, CIE $a^* = -0.43$, CIE $b^* = +1.98$, consisting of an 8 mm diameter measuring area and a 50 mm diameter illumination area. The color values (CIE L^* , a^* , and b^*) were measured on sample surfaces.

Texture profile analysis (TPA) Samples were cooked as previously described. The cooked blood sausages were cooled at room temperature for 1 h and the textural properties were measured. The textural properties of each sausage were measured using a spherical probe (5 cm), attached to a texture analyzer (TA-XSK1i; Stable Micro

System Ltd., Surrey, UK). The test conditions were as follows: stroke, 20 g; test speed, 2.0 mm/s; and distance, 20.0 mm. Data were collected and analyzed in terms of hardness (N), springiness, cohesiveness, gumminess (N), and chewiness (N) values.

Thiobarbituric acid reaction substance (TBARS) values Lipid oxidation was assessed using a method described by Tarladgis *et al.* (16). The absorbance was measured at 538 nm (Libra S22; Biochrom Ltd., Cambridge, England), against a blank prepared with distilled water (5 mL) and TBA-reagent (5 mL). The K value was calculated using 1,1,3,3-tetraethoxypropane (Sigma-Aldrich, St. Louis, MO, USA) as the standard and TBARS values were calculated by multiplying the absorbance values by the K values.

Sensory evaluation Twenty-four 24 semi-trained panelists (aged 20-55 years) were recruited from faculty and students who had previous descriptive analysis experience with meat and meat products. The sensory evaluation was performed in meat science laboratory under white fluorescence lighting. Panelists were instructed to cleanse their palates between the samples testing with water. The samples were cooled to room temperature at 25±1°C, cut and served to the panelists in random order. The color, flavor, tenderness, juiciness, warmed-over flavor, vinegar flavor, and overall acceptability of the samples were evaluated using a 10-point descriptive scale (1=extremely undesirable, 10=extremely desirable).

Statistical analysis For each batch, there are 5 treatments (1 kg/treatment) and all measurements were conducted at least three times for each experimental condition. All values were presented as means±standard error (SE). An analysis of variance for chemical composition, swelling yield, pH values, cooking loss, color, TPA, sensory property data was performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (17). The Duncan's multiple range test ($p < 0.05$) was used to determine the differences among treatments.

Relationship between chemical composition and texture profile analysis was assessed using the simple linear regression procedure with Microsoft® Excel 2010 (Microsoft, Redmond, WA, USA).

Results and Discussion

Chemical composition Moisture content ranged from 45.01 to 60.80% and fat content ranged from 15.72 to 27.04% (Table 1). The SPS with various natural vinegars had higher moisture and lower fat content ($p < 0.05$) than control. These results might be due to hold moisture and flow out fat during swelling. The protein and ash contents of control were the highest ($p < 0.05$) among all the treatments.

Acid pre-treatment of the pig skin enabled swelling and collagen solubilization due to the break down of non-covalent protein bonds

Table 1. Chemical composition and swelling yield of swelled pig skin (SPS) with various natural vinegars

Traits	Treatment				
	Control	<i>Bokbunja</i> vinegar	Brown rice vinegar	Cider vinegar	Lemon vinegar
Moisture (%)	45.01±0.43 ^{B1)}	59.29±0.23 ^A	60.80±0.63 ^A	60.62±0.32 ^A	59.49±0.18 ^A
Protein (%)	25.04±0.28 ^A	20.91±0.14 ^B	20.63±0.51 ^B	21.23±0.22 ^B	21.02±0.76 ^B
Fat (%)	27.04±0.25 ^A	15.81±0.12 ^B	15.72±0.10 ^B	15.76±0.18 ^B	15.83±0.20 ^B
Ash (%)	0.08±0.01 ^A	0.06±0.01 ^B	0.05±0.00 ^B	0.06±0.01 ^B	0.05±0.00 ^B
Swelling yield (%)	-	152.4±0.11 ^B	155.9±0.10 ^A	156.6±0.11 ^A	154.7±0.17 ^{A,B}

¹⁾All values are mean±SE; ^{A-C}Means within rows with different superscript letters are significantly different ($p<0.05$).

Table 2. Chemical composition of Korean blood sausage containing swelled pig skin (SPS) with various natural vinegars

Traits	Treatment				
	Control	<i>Bokbunja</i> vinegar	Brown rice vinegar	Cider vinegar	Lemon vinegar
Moisture (%)	64.02±0.67 ^{B1)}	68.55±1.02 ^A	70.13±0.81 ^A	69.79±1.22 ^A	69.29±0.88 ^A
Protein (%)	15.82±0.38 ^A	15.02±0.31 ^B	15.14±0.22 ^B	15.04±0.29 ^B	15.06±0.15 ^B
Fat (%)	13.31±0.34 ^A	6.82±1.08 ^B	6.69±0.99 ^B	6.67±0.81 ^B	6.89±1.04 ^B
Ash (%)	2.26±0.09	2.22±0.12	2.20±0.07	2.18±0.09	2.18±0.04

¹⁾All values are mean±SE; ^{A-B}Means within rows with different superscript letters are significantly different ($p<0.05$).

Table 3. The physico-chemical and texture profile analysis (TPA) of Korean blood sausage added containing swelled pig skin (SPS) with various natural vinegars

Traits	Treatment				
	Control	<i>Bokbunja</i> vinegar	Brown rice vinegar	Cider vinegar	Lemon vinegar
Cooking loss (%)	4.83±0.55 ^{B1)}	5.05±0.58 ^B	5.91±0.31 ^A	5.93±0.45 ^A	5.60±0.26 ^B
pH	6.22±0.05 ^A	5.83±0.01 ^B	5.86±0.04 ^B	5.83±0.02 ^B	5.83±0.01 ^B
TBARS (mgMA/kg meat)	0.37±0.02 ^A	0.24±0.01 ^{BC}	0.22±0.01 ^C	0.26±0.02 ^B	0.23±0.02 ^{BC}
CIE L*	11.53±1.64 ^C	17.62±1.11 ^A	13.15±1.40 ^B	13.47±0.94 ^B	13.09±0.98 ^B
CIE a*	0.36±0.01 ^B	0.39±0.01 ^A	0.40±0.02 ^A	0.39±0.02 ^A	0.39±0.01 ^A
CIE b*	0.33±0.01	0.34±0.01	0.34±0.01	0.33±0.01	0.33±0.01
Hardness (N)	27.53±1.31 ^A	22.42±0.84 ^B	22.37±1.45 ^B	20.87±2.08 ^B	22.69±2.32 ^B
Springiness	0.53±0.04 ^C	0.61±0.03 ^B	0.70±0.07 ^A	0.58±0.04 ^{BC}	0.70±0.06 ^A
Cohesiveness	0.14±0.02 ^A	0.11±0.02 ^B	0.15±0.02 ^A	0.12±0.02 ^{A,B}	0.13±0.02 ^{A,B}
Gumminess (N)	4.00±0.63 ^A	2.51±0.68 ^B	3.45±0.70 ^{AB}	2.64±0.73 ^B	2.95±0.67 ^B
Chewiness (N)	2.12±0.52 ^{AB}	1.53±0.49 ^B	2.42±0.45 ^A	1.53±0.57 ^B	2.07±0.49 ^{A,B}

¹⁾All values are mean±SE; ^{A-C}Means within rows with different superscript letters are significantly different ($p<0.05$).

(18). The SPS with cider vinegar had the highest (156.6%) swelling yield because cider vinegar has higher degree of peptidization of collagen in pig skin compared to other treatment (19), whereas the SPS with *Bokbunja* vinegar had the lowest (152.4%) swelling yield.

Application of various natural vinegars in swelling process effected on chemical composition of SPS except for ash content ($p<0.05$) (Table 2). The moisture content of samples with added SPS was higher than samples without SPS probably because the SPS had more moisture during swelling. Osburn *et al.* (5) reported that adding water to the pig skin connective tissue gel process increases the moisture content in bologna containing pig skin connective tissue gel. Treatment with SPS resulted in a significantly lower fat and protein content than treatments without SPS, suggesting that soluble fat was washed out in the rinse step and increase of moisture content resulted in decrease of protein content, relatively. The addition of SPS did not have a significant effect on the ash contents.

Physico-chemical analyses The cooking loss of blood sausage containing SPS with natural vinegar ranged from 5.05 to 5.93% (Table 3). A significant difference ($p<0.05$) was observed in the cooking loss of blood sausages containing SPS treated brown rice and cider vinegars when compared to the control (4.83%). This was probably due to fact that the higher swelling yield resulted in an additional moisture content that could be lost during cooking. Samples containing SPS with brown rice and cider vinegar that had the highest ($p<0.05$) swelling yield also had the highest ($p<0.05$) cooking loss among the treatments. In spite of the swelling processing, the meat product samples containing SPS with *Bokbunja* and lemon vinegars had similar ($p>0.05$) cooking loss to samples without swelling step.

Table 3 shows the pH, and L*, a*, and b* values of blood sausages containing SPS with various natural vinegars. The pH values (6.22) of meat product sample with no SPS were the highest of all treatments.

Table 4. Relationship between chemical composition and texture profile analysis of Korean blood sausage containing swelled pig skin (SPS) with various natural vinegars

Chemical composition		Texture profile analysis (TPA)				
		Hardness	Springiness	Cohesiveness	Gumminess	Chewiness
Moisture	Correlation coefficient	0.69	0.58	0.17	0.44	0.09
	Slope	-0.59**	17.66*	-18.80 ^{NS}	-1.29*	-0.38 ^{NS}
	SER	1.79	2.00	2.43	2.22	2.46
Fat	Correlation coefficient	0.53	0.46	0.26	0.58	0.33
	Slope	0.08**	-2.06*	7.10*	0.23*	0.14 ^{NS}
	SER	0.34	0.17	0.16	0.23	0.03

SER, standard error of regression fit; NS, not significant, * $p < 0.05$, ** $p < 0.001$.

Acidic properties of various vinegars had an effect on end of pH values for sausage samples in neutralizing step. Similarly, Kim *et al.* (20) reported that pH values of soaking solution influence pH values at end of neutralizing process. No differences were observed in the pH values among treatments containing SPS and various natural vinegars. This result may be due to pH values of various vinegars being controlled at the same condition (pH 5.8).

The L^* values of blood sausages without/with SPS and various natural vinegars ranged from 11.53–17.62. The L^* values of sausage samples containing SPS and natural vinegars were higher ($p < 0.05$) than those of the control. Osburn *et al.* (5) found that the addition of pig skin connective tissue increases the lightness of bologna. Mac Dougall *et al.* (21) reported that the L^* values are related to the hemoglobin content. However, L^* values were not affected by hemoglobin content because same amount of pork blood was added to all treatments in this study. The control had the lowest a^* values because it had the highest fat content. Other treatments containing SPS with various natural vinegars had a redder color ($p < 0.05$) than that of the control. Similar results have been reported for frankfurters, which had higher a^* values with decreasing fat content (22). No significant differences were observed in the b^* values between the control and samples containing SPS and various natural vinegars. The color of a meat product is one of the most important quality factors when consumers make meat product purchasing decisions (23). However, color of blood sausages is not substantial factor in this study because the meat samples containing blood are changed to black by cooking.

The texture profile of a meat product can be changed by the moisture, fat content, condition of the raw materials, the kinds of additives used and thermal protein denaturation by cooking (24). Previous study reported that adding gelatin from pig skin collagen may be desirable for texture, and consumer preference in meat products (25). The TPA of blood sausages containing SPS with various natural vinegars is presented in Table 3. Samples containing SPS with various natural vinegars were softer ($p < 0.05$) compared to that of the control. The softer texture of the blood sausage containing SPS with various natural vinegars may have resulted from the swelling yield of the pig skin and moisture content. Similar results were reported by

Jones (26), who found that adding collagen to a meat product formulation resulted in a softer texture due to the dilution of the strong binding myofibrillar proteins in the meat product. Moreover, moisture content found to be negatively correlated ($r = 0.69$, slope = -0.59 ; $p < 0.001$) with hardness in blood sausages (Table 4). Samples containing SPS with brown rice and lemon vinegar had the highest springiness ($p < 0.05$) and the control had the lowest springiness ($p < 0.05$) because of lowest moisture content in all treatments. Table 5 indicated springiness related with moisture ($r = 0.58$, slope = 17.66) and fat content ($r = 0.46$, slope = -2.06) with significant correlation on blood sausage. In other words, the increase in swelling yield, having higher moisture content, of pig skin may have resulted in a softer texture and higher springiness with significant ($r = 0.69$, slope = -0.59 ; $p < 0.001$) ($r = 0.58$, slope = 17.66 ; $p < 0.05$) correlation. Li *et al.* (27) found that increasing the water content resulted in a decrease in the cohesiveness. In this study, there was no significant correlation between moisture content and cohesiveness. However, we found significant ($r = 0.26$, slope = 7.10 ; $p < 0.05$) correlation between fat content and cohesiveness. Gumminess values for the control and samples containing SPS with brown rice vinegar were significantly higher ($p < 0.05$) than those of other treatments. The results related with moisture and fat content had a significant ($r = 0.44$, slope = -1.29 ; $p < 0.05$) ($r = 0.58$, slope = 0.23 ; $p < 0.05$) correlation for the gumminess. Sausage samples containing SPS with brown rice vinegar had the highest chewiness (2.42 N) ($p < 0.05$) of all treatments. Totally, Addition of SPS with brown rice and lemon vinegars greatly improved TPA properties on blood sausages.

TBARS values We found that the TBARS values of blood sausages containing SPS with various natural vinegars ranged from 0.22 to 0.37 mg MDA/kg meat (Table 3), suggesting that adding blood may have accelerated oxidation of the meat product. Brewer *et al.* (28) reported that fresh meat has about 0.15–0.2 mg MDA/kg meat. In this study, the control had the highest TBARS values ($p < 0.05$), whereas treatments containing SPS and *Bokbunja*, brown rice, and lemon vinegars had the lowest ($p < 0.05$) TBARS values. These results indicate that components in various natural vinegars, including polyphenols, flavonoids, and vitamin C have lipid oxidation inhibition

Table 5. Sensory evaluation of Korean blood sausage containing swelled pig skin (SPS) with various natural vinegars

Traits	Treatment				
	Control	<i>Bokbunja</i> vinegar	Brown rice vinegar	Cider vinegar	Lemon vinegar
Color ²⁾	8.00±0.73 ¹⁾	8.50±0.52	8.42±0.66	8.50±0.52	8.42±0.51
Flavor	8.00±0.85	8.08±0.90	8.33±0.88	7.67±1.15	7.58±1.44
Warmed-over flavor	7.42±0.51 ^C	9.08±0.29 ^A	8.50±0.52 ^B	7.98±0.52 ^{BC}	8.08±0.29 ^B
Vinegar flavor	9.42±1.56 ^A	8.00±1.59 ^{AB}	8.67±1.37 ^A	6.17±0.79 ^D	7.25±0.75 ^C
Tenderness	7.25±0.76 ^B	7.50±0.67 ^{AB}	8.50±0.52 ^A	8.00±0.74 ^A	7.50±0.67 ^{AB}
Juiciness	7.42±0.52 ^B	7.83±0.58 ^{AB}	8.08±0.80 ^A	7.75±0.75 ^{AB}	7.42±0.52 ^B
Overall acceptability	7.67±0.49 ^B	8.17±0.24 ^A	8.25±0.45 ^A	7.58±0.51 ^B	7.67±0.65 ^B

¹⁾All values are mean±SE; ^{A-C} Means within rows with different superscript letters are significantly different ($p<0.05$).

²⁾Color, flavor, warmed-off flavor, vinegar flavor, tenderness, juiciness and overall acceptability: 1=extremely undesirable, 10=extremely desirable.

activity. Park and Chin (29) found that the *Bokbunja* extract, which contains antioxidants such as polyphenols and anthocyanins, decreased TBARS values in pork patties.

Sensory evaluation No differences in color were observed between the control and treatments containing SPS and various natural vinegars (Table 5). This may have occurred because of the darker color of the meat product with blood. Moreover, the addition of SPS and various natural vinegars did not affect the flavor in any of the treatments. However, the addition of SPS and various natural vinegars contributed to a decrease ($p<0.05$) in the warmed-over flavor of blood sausages when compared to the control. In other words, the flavor of the various natural vinegars may have reduced the warmed-over flavor by cooking the blood. However, sausage samples containing SPS with cider and lemon vinegars had the highest ($p<0.05$) vinegar flavor. Samples containing SPS with brown rice and cider vinegars, which had the highest swelling yields, were significantly more tender and juicier than the other samples. blood sausage samples containing SPS with brown rice and *Bokbunja* vinegars had higher ($p<0.05$) overall acceptability scores than treatments with raw pig skin. Sadler and Young (30) noted that panelists preferred sausages with preheated beef tendon to sausages containing raw tendon in the sensory texture and overall acceptability analysis. Blood sausages containing SPS with cider and lemon vinegars had no significant differences in overall acceptability compare to control. This result might be because strong vinegar flavor gave negative effects to panels on overall acceptability. Therefore, we conclude that adding SPS with various natural vinegars to the blood sausage formulation can improve the quality characteristics and warmed-over flavor of blood sausages. Future studies would examine the effect of SPS and various natural vinegars on inhibiting lipid and protein oxidation in blood sausages during chilled storage.

Disclosure The authors declare no conflict of interest.

References

- Sohn JW, Yum CA, Kim CJ. Effects of binding materials on sensory and cooking properties of *Soondae*. Korean J. Food Cook. Sci. 15: 191-196 (1999)
- Osburn WN. Improving the functionality of recovered tissue protein. PhD thesis, University of Nebraska Lincoln, Lincoln, NE, USA (1996)
- Gómez-Guillén MC, Giménez B, López-Caballero ME, Montero MP. Functional and bioactive properties of collagen and gelatin from alternative sources: A review. Food Hydrocolloid. 25: 1813-1827 (2011)
- Bailey AJ, Light ND. Connective tissue in meat and meat products. Elsevier Applied Science Publishers Ltd., London, UK. pp. 325-326 (1989)
- Osburn WN, Mandigo RW, Eskridge KM. Pork skin connective tissue gel utilization in reduced-fat bologna. J. Food Sci. 62: 1176-1182 (1997)
- Jeong YJ. Current trends and future prospects in the Korean vinegar industry. Food Sci. Ind. 42: 52-59 (2009)
- Xu QP, Tao WY, Ao ZH. Analysis of source of antioxidant compounds in Zhenjiang vinegar. Food Ferment. Ind. 3: 127-130 (2005)
- Liu F, Yusuf BL, Zhong J, Feng L, He Y, Wang L. Variety identification of rice vinegars using visible and near infrared spectroscopy and multivariate calibrations. Int. J. Food Prop. 14: 1264-1276 (2011)
- Ohtsubo K, Suzuki K, Yasui Y, Kasumi T. Bio-functional components in the processed pre-germinated brown rice by a twin-screw extruder. J. Food Compos. Anal. 18: 303-316 (2005)
- Beveridge T, Franz K, Harrison JE. Clarified natural apple juice: Production and storage stability of juice and concentrate. J. Food Sci. 51: 411-414 (1986)
- Tripoli E, Guardia ML, Giammanco S, Majo DD, Giammanco M. Citrus flavonoids: Molecular structure, biological activity and nutritional properties: A review. Food Chem. 104: 466-479 (2007)
- Ko MS, Yang JB. Effects vinegar on lipid oxidation and meat color of chilled pork. Bull. Dongnam Health Coll. 20: 491-498 (2002)
- Yoon I, Wee JH, Moon JH, Ahn TH, Park, KH. Isolation and identification of quercetin with antioxidative activity from the fruits of *Rubus coreanus* Miquel. Korean J. Food Sci. Technol. 35: 499-502 (2003)
- Jin TY, Quan WR, Wang MH. Manufacturing characteristics and physicochemical component analysis of *Bokbunja* (*Rubus coreanus* Miquel) jelly. J. Korean Soc. Food Sci. Nutr. 39: 554-559 (2010)
- AOAC. Official Method of Analysis of AOAC Intl. 18th ed. Method 934.01. Association of Official Analytical Chemists, Gaithersburg, MD, USA (2005)
- Tarladgis B, Watts B, Younathan M, Dugan L. A distillation method for the quantitative determination of malonaldehyde in rancid foods. J. Am. Oil Chem. Soc. 37: 44-48 (1960)
- SAS. The SAS/STAT User's Guide. Ver. 9.3. SAS Institute Inc., Cary, NC, USA (2011)
- Stainsby G. Gelatin gels. pp. 209-222. In: Advances in Meat Research: Collagen as a Food. Pearson AM, Dutson TR, Bailey AJ (eds). Van Nostrand Reinhold Company Inc., New York, NY, USA (1987)
- Ranganayaki MD, Asghar A, Henrickson RL. Influence of anion and cation on the water-holding capacity of bovine hide collagen at different pH values. Effect of sodium chloride and polyphosphates on hydration. J. Food Sci. 47: 705-710 (1982)
- Kim HW, Song DH, Choi YS, Kim HY, Hwang KE, Park JH, Kim YJ, Choi JH, Kim CJ. Effects of soaking pH and extracting temperature on the physicochemical properties of chicken skin gelatin. Korean J. Food Sci. An. 32: 316-322 (2012)

21. Hutchings JB. Food colour and appearance. Springer Science Business Media, Bedford, UK. pp. 400-412 (1994)
22. Grigelmo-Miguel N, Abadías-Serós MI, Martín-Belloso O. Characterisation of low-fat high-dietary fibre frankfurters. *Meat Sci.* 52: 247-256 (1999)
23. Mancini RA, Hunt MC. Current research in meat color. *Meat Sci.* 71: 100-121 (2005)
24. Song HI, Moon GI, Moon YH, Jung IC. Quality and storage stability of hamburger during low temperature storage. *Korean J. Food Sci. An.* 20: 72-78 (2000)
25. Puolanne E, Ruusunen M. The properties of connective tissue membrane and pig skin as raw materials for cooked sausage. *Meat Sci.* 5: 371-382 (1981)
26. Harold DH, Robert GZ. Low-fat meats design strategies and human implications. Academic Press. Inc., San Diego, CA, USA. pp. 113-128 (1994)
27. Li R, Carpenter JA, Cheney R. Sensory and instrumental properties of smoked sausage made with mechanically separated poultry (MSP) meat and wheat protein. *J. Food Sci.* 63: 923-929 (1998)
28. Brewer MS, Ikins WG, Harbers CAZ. TBA values, sensory characteristics, and volatiles in ground pork during long-term frozen storage: Effects of packaging. *J. Food Sci.* 8: 326-330 (1992)
29. Park SY, Chin KB. Evaluation of antioxidant activity in pork patties containing *Bokbunja* (*Rubus coreanus*) extract. *Korean J. Food Sci. An.* 27: 432-439 (2007)
30. Sadler DHN, Young OA. The effect of preheated tendon as a lean meat replacement on the properties of fine emulsion sausages. *Meat Sci.* 35: 259-268 (1993)