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Effect of fermented red beet extracts on the shelf stability of low-salt frankfurters

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Abstract The effect of fermented red beet (FRB) on shelf-life of low-salt frankfurters stored for 4 weeks was investigated. The pH, volatile basic nitrogen (VBN), lightness, and yellowness of frankfurters decreased with increasing levels of FRB, whereas the redness of frankfurters increased with increasing levels of FRB. The VBN, thiobarbituric acid reactive substance values, total viable count, and redness of all treatments decreased with increasing period of refrigeration storage. The appearance, color, and juiciness scores of the control and treatments decreased with increasing period of refrigeration storage. However, there was no significant ($p > 0.05$) difference among the treatments except for the color of T3 (3.0% FRB) and juiciness of T4 (5.0% FRB). The flavor, tenderness, and overall acceptability scores of all the treatments decreased with increasing storage periods. These results demonstrated that FRB can be added to low-salt frankfurters to maintain their qualities and extend the shelf-life of refrigerated storage.

Keywords Red beet · Ascorbic acid · Frankfurter · Lipid oxidation · Sensory properties

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Introduction

Frankfurters are among the oldest processed meat products that have high acceptance worldwide. Microbial growth, lipid oxidation, and color during storage are important factors that affect the shelf-life and consumer's acceptance of frankfurters [1]. Low-salt frankfurters usually have a short shelf-life and are prone to bacterial growth [2, 3]. The color pigments, lipids, and proteins of meat products may degrade during storage, which can contribute to deterioration in flavor, texture, color, and nutritional value [4]. Lipid oxidation limits the shelf-life of meat products by reducing their quality and accelerating deterioration [5]. To inhibit lipid oxidation, antioxidants have been used for over 50 years [6]. Synthetic antioxidants such as butylated hydroxyaniso and butylated hydroxytoluene have been widely used in the meat industry to prevent lipid oxidation [7]. However, synthetic antioxidants have possible health risks and toxicities [8]. In addition, meat products that are free of conventional chemical substances are increasing in demand [9, 10]. Therefore, the meat processing industry is actively searching for alternative technology to increase the shelf-life of meat product by utilizing natural and organic sources. Natural plant products are being used as promising technologies to increase the shelf-life of meat product.

Vegetables contain significant amounts of natural antioxidants [6, 9]. In recent years, there has been increased interest in using fermented vegetable extracts as natural antioxidants for meat products because fermentation of vegetable materials offers a promising method of preservation. Red beet (*Beta vulgaris* L.) is primarily cultivated for its roots that have high nutritional values. Red beet roots are usually consumed after processing [11, 12]. Red beet has been used in food technology as a source of antioxidants. It contains bioactive compounds such as

phenolics and cyclic amine as well as various minerals [13]. It has been reported that red beet extracts have high potency as antioxidants in meat products [13]. Lichtenthäler and Marx [14] reported that the fermentation process enhanced the antioxidant capacities of numerous different types of food such as beetroot, carrot, pomegranate juice, and soybean. However, limited information is available in the literature on the shelf-life of meat products added with fermented natural extracts. Thus, the objective of this study was to determine the effect of fermented red beet on shelf stability of low-salt frankfurters stored for 4 weeks.

Materials and methods

Preparation of fermented red beet (FRB)

Commercial samples of hot air dried reed beet (Chungwon Inc., Jincheon, North Chungcheong, South Korea) were purchased from a local market. Ten gram of beet powders was mixed with 100 mL of distilled water for 30 min. Furthermore, 0.025% nitrate reductase-active culture containing *Staphylococcus carnosus* (S-B-61, Bactoferm^{TM}, Chr. Hansen Inc., Gainesville, Fla., USA) was added to the mixture, followed by incubation in a shaker incubator at 30 °C for 24 h. The mixture was filtered (Whatman No. 1 filter paper) and evaporated (EYELA N-1000, Rikakikai, Japan) at <50 °C. Concentrated products of FRB (pH: 4.56, L^*-value: 5.45, a^*-value: 3.35, b^*-value: 8.30, nitrite content: 748.51 ppm, DPPH scavenging activity: 47.83%, ferrous iron chelating ability: 23.14%, total phenol contents: 30.76 mg of gallic acid equivalent/g, total flavonoid contents: 15.16 mg of hesperidin equivalent/g) were then stored in amber flasks in the dark at 4 °C until used within 24 h [2, 10].

Preparation of frankfurters

Fresh pork ham (*M. biceps femoris*, *M. semitendinosus*, *M. semimembranosus*) and pork back fat (fat 85.64%) were purchased from a local processor at 48 h postmortem. Pork ham and pork back fat were initially ground through an 8-mm plate. Five different groups of low-salt frankfurters were produced. The experimental design and compositions of these frankfurters are shown in Table 1. The first group of frankfurters (NaCl 1.5%) served as controls. They were prepared without adding antioxidants. The remaining four groups (NaCl 1.0%) were prepared with the following: T1, 0.05% ascorbic acid; T2, 1.0% FRB; T3, 3.0% FRB; T4, 5.0% FRB. Ground meats were homogenized and ground for 1 min 30 s in a silent cutter (Nr-963009; Hermann Scharfen GmbH & Co., Germany). Pork back fat, sodium chloride (1.0%), and sodium tripolyphosphate (0.15%) were added to the meat and mixed for 1 min 30 s. Meat batters were homogenized for 3 min. A temperature probe (KM330; Kane-May, UK) was used to monitor the temperature of the batter to maintain the temperature below 10 °C throughout the batter preparation. After batter preparation, the meat batter was stuffed into #240 collagen casings (NIPPI Inc., Tokyo, Japan; approximate diameter, 25 mm) using a stuffer (IS-8; Sirman, Italy). Meat batters were dried at 45 °C for 30 min, heated at 80 °C for 60 min in a chamber (MAXi3501; Kerres, Germany), and cooled at 21 °C for 3 h. This procedure was performed in triplicates for each low-salt frankfurter group [15].

Table 1 Low-salt frankfurters formulations with FRB. (unit: g/100 g)

Ingredients	Treatments				
	Control	T1	T2	T3	T4
Pork ham	50	50	50	50	50
Pork back fat	25	25	25	25	25
Ice	25	25	25	25	25
Total	100	100	100	100	100
Sodium chloride (NaCl)	1.5	1.0	1.0	1.0	1.0
Sodium tripolyphosphate	0.15	0.15	0.15	0.15	0.15
Sea mustard	1.0	1.0	1.0	1.0	1.0
Transglutaminase	1.0	1.0	1.0	1.0	1.0
Ascorbic acid	–	0.05	–	–	–
Fermented red beet (FRB)	–	–	1.0	3.0	5.0

pH

The pH values of low-salt frankfurters were measured in a homogenate prepared with 5 g of sample and 20 mL distilled water using a pH meter (pH 6000, Thermo Eutech, Singapore).

Volatile basic nitrogen (VBN) value

VBN (mg%) was measured by the modified micro diffusion assay according to the method of Pearson [16]. VBN was performed to determine the extent of protein deterioration during refrigerated storage.

Thiobarbituric acid reactive substance (TBARS) values

Lipid oxidation was assessed in triplicate using the TBARS method of Tarladgis et al. [17] with minor modifications and was expressed as miligrams of malondialdehyde (MD) per kg of low-salt frankfurter [6].

Microbiological analysis

To determine the total viable count (TVC) for each sample during storage, 25 g of samples was aseptically transferred into a sterile stomacher bag containing 225 mL of 0.1% peptone water, followed by pummeling samples into a stomacher (Masticater-Paddle-Blender, IUL Instrument, Barcelona, Spain) for 3 min. The homogenates were serially diluted with 0.1% peptone water. Serially diluted samples (1 mL) were then placed in Petri dishes. A total of 20 mL of plate count agar (Difco, Sparks, MD, USA) was then poured over the plates containing serially diluted samples. After the medium was solidified, the plates were incubated at 37 °C for 48 h and the colonies developed on the plates were manually counted.

Color attribute

Color changes in the low-salt frankfurters during refrigerated storage were monitored by the CIE Lab system using a colorimeter (Chroma meter CR-410, Minolta, Japan; illuminate C, calibrated with white plate, CIE $L^* = +97.83$, $a^* = -0.43$, $b^* = +1.98$). Color was expressed with CIE L^* (100 = white, 0 = black), CIE a^* (positive = redness, negative = greenness), and CIE b^* (positive = yellowness, negative = blueness) values. Color readings were measured on ten randomly chosen spots on the frankfurters and were utilized as an estimate of meat discoloration.

Sensory evaluation

A trained 12-member panel comprising researchers from the Department of Food Processing Research Center at Korea Food Research Center (KFRI) in Korea evaluated these low-salt frankfurters. Each low-salt frankfurter was evaluated in terms of appearance, color, flavor, tenderness, juiciness, and overall acceptability. These low-salt frankfurters were cut into quarters (size: 5 × 5 × 3 cm) and served to the panelists randomly. Sensory evaluations were performed under white fluorescent lighting. The panelists were instructed to clean their palates between samples using water. The appearance, color, flavor, tenderness, juiciness, and overall acceptability of cooked samples were evaluated using a 10-point descriptive scale with Hedonic test wherein 1 = extremely undesirable, 10 = extremely desirable [18].

Statistical analysis

A 5 × 5 factorial design with three replicates was employed for storage data (pH, VBN, TBARS, TCA, color, and sensory evaluations). The treatments and storage periods (0, 1, 2, 3, and 4 weeks) were used as main factors in two-way analysis of variance. Analysis of variance was performed for all variables using the General Linear Model procedure of the SPSS 18.0 software (SPSS Inc., Chicago, IL, USA). Duncan's multiple range test was used to determine differences between treatment means. Mean values and standard deviation of the means were reported. Statistical significance was considered when p value was less than 0.05.

Results and discussions

Changes in pH of low-salt frankfurters during refrigerated storage

pH is associated with the chemical/microbiological reactions occurring during food deterioration and effectively reflects food stability as a dependable indicator [6]. The pH values of low-salt frankfurters formulated with FRB during refrigerated storage for 4 weeks are summarized in Table 2. The pH values of frankfurters decreased when the levels of FRB increased. This might be due to the fermentation process of red beet by microorganisms (pH change from 6.10 to 4.56 after fermentation). Similar results have been reported by Djeri and Williams [9]. They have showed that the pH values of bologna sausage with added fermented celery juice powder are lower than those of controls without adding fermented celery juice powder. In contrast, Kang and Lee [19] have indicated that the pH values of sausages added with or without red beet are not significantly different. Lee and Chin [13] also reported that red beet extracts added to pork patties did not significantly influence the pH values. This study showed different results when red beet was unfermented. In this current study, the pH values of all treatments were increased during 3 weeks of refrigeration, which decreased until the end of storage. These results might be due to accumulation of lactic acid generated by proliferating microorganisms [20]. Our results are in agreement with the results of Kim et al., [21]. They have reported that the pH values of ground pork treated with rice bran decreased during storage. The pH of meat products can be influenced by the relative difference between the presence of Gram-positive and Gram-negative bacteria. Gram-positive bacteria produce organic acids and decrease the pH of meat products, whereas Gram-negative bacteria produce ammonia and increase the pH [5].

Changes in VBN of low-salt frankfurters during refrigerated storage

The VBN value can be used as an important indicator of deterioration in meat products during storage periods

Table 2 Changes in pH of low-salt frankfurters formulations with FRB during refrigerated storage for 4 weeks

	Storage period (weeks)				
	0	1	2	3	4
Control	6.34 ± 0.03^{aC}	6.35 ± 0.02^{aC}	6.39 ± 0.03^{aB}	6.51 ± 0.02^{aA}	6.28 ± 0.02^{aD}
T1	5.68 ± 0.04^{bB}	6.01 ± 0.03^{cA}	6.06 ± 0.03^{cA}	6.08 ± 0.01^{cA}	5.22 ± 0.02^{eC}
T2	6.33 ± 0.02^{aB}	6.34 ± 0.02^{aB}	6.37 ± 0.02^{aB}	6.49 ± 0.02^{aA}	5.41 ± 0.14^{dC}
T3	6.30 ± 0.02^{aAB}	6.26 ± 0.03^{bB}	6.35 ± 0.04^{bA}	6.38 ± 0.02^{bB}	5.78 ± 0.11^{cC}
T4	6.29 ± 0.02^{aA}	6.24 ± 0.02^{bA}	6.32 ± 0.02^{bA}	6.37 ± 0.01^{bA}	6.02 ± 0.13^{bB}

All values are mean ± SD of three replicates

Control: frankfurter with 1.5% NaCl, *T1* frankfurter with 1.0% NaCl + 0.05% ascorbic acid, *T2* frankfurter with 1.0% NaCl + 1.0% FRB, *T3* frankfurter with 1.0% NaCl + 3.0% FRB, *T4* frankfurter with 1.0% NaCl + 5.0% FRB

[a–e] Means sharing different letters in the same column are significantly different ($p < 0.05$)

[A–D] Means sharing different letters in the same row are significantly different ($p < 0.05$)

[8, 21]. It can be affected by the compositions of protein such as amino acid decarboxylase during storage and enzymes as well as microorganisms [20]. The effects of different levels of FRB on VBN of low-salt frankfurters over 4 weeks of refrigerated storage are summarized in Table 3. The VBN values of the control and T4 (1.0% NaCl and 5.0% FRB) were lower than those of other treatments at 0 weeks. During refrigerated storage, the highest VBN value was found in the treatment with T1 (1.0% NaCl and 0.05% ascorbic acid). At the end of the storage period (4 weeks), the VBN value of the control was the lowest. There was no significant ($p > 0.05$) difference between treatment containing control or T4. According to the results, it can be noted that the salt content significantly affects the VBN content, which increased when the salt level decreased from 1.5 to 1.0%. This finding can be explained by the function of salt that inhibits proteolysis caused by microorganisms and enzymes in meat products [22]. Therefore, a low-salt concentration generates the decomposition of protein, leading to a high VBN content [23]. However, the addition of FRB controls the protein deterioration of pork sausage during storage time since the VBN contents decreased with increasing FRB level. This could be due to some antimicrobial compounds from FRB, which prevents microbial growth during storage periods. SPISLP [24] recommended that raw and packed meat with VBN content of 20 mg% is considered to be a threshold value to evaluate the degree of freshness. Kim et al. [25] reported that many meat products do not decay, although their VBN content is 30 mg%. In this study, VBN contents

Table 3 Changes in VBN and TBARS of low-salt frankfurters formulations with FRB during refrigerated storage for 4 weeks

	Storage period (weeks)				
	0	1	2	3	4
VBN mg%					
Control	6.44 ± 0.65^{cE}	11.30 ± 0.64^{dD}	15.73 ± 1.10^{dC}	17.63 ± 0.64^{cB}	18.20 ± 0.79^{dA}
T1	7.14 ± 0.96^{bD}	15.44 ± 1.02^{aC}	21.29 ± 2.16^{aB}	22.89 ± 1.94^{aB}	28.62 ± 1.54^{aA}
T2	8.12 ± 1.26^{aD}	14.87 ± 0.92^{bC}	17.54 ± 1.30^{bB}	18.44 ± 0.97^{bB}	26.32 ± 1.74^{bA}
T3	7.36 ± 1.03^{bD}	12.56 ± 0.52^{cC}	16.27 ± 1.46^{cA}	17.22 ± 0.71^{cB}	19.74 ± 0.54^{cA}
T4	6.82 ± 0.56^{cD}	11.14 ± 1.05^{dC}	15.97 ± 2.93^{dB}	15.51 ± 1.11^{dB}	19.69 ± 1.17^{cdA}
TBARS mg MD/kg					
Control	0.14 ± 0.02^{aE}	0.27 ± 0.01^{bD}	0.34 ± 0.04^{bC}	0.39 ± 0.04^{bB}	0.48 ± 0.03^{aA}
T1	0.13 ± 0.01^{aE}	0.29 ± 0.02^{aD}	0.40 ± 0.02^{aC}	0.45 ± 0.03^{aB}	0.49 ± 0.03^{aA}
T2	0.14 ± 0.02^{aD}	0.23 ± 0.01^{cC}	0.24 ± 0.03^{cBC}	0.26 ± 0.02^{dB}	0.34 ± 0.04^{cA}
T3	0.14 ± 0.02^{aE}	0.23 ± 0.02^{cD}	0.26 ± 0.02^{cC}	0.32 ± 0.03^{cB}	0.38 ± 0.03^{bA}
T4	0.13 ± 0.01^{aD}	0.24 ± 0.02^{cC}	0.27 ± 0.03^{cC}	0.30 ± 0.03^{cB}	0.36 ± 0.02^{bcA}

All values are mean ± SD of three replicates

Control: frankfurter with 1.5% NaCl, *T1* frankfurter with 1.0% NaCl + 0.05% ascorbic acid, *T2* frankfurter with 1.0% NaCl + 1.0% FRB, *T3* frankfurter with 1.0% NaCl + 3.0% FRB, *T4* frankfurter with 1.0% NaCl + 5.0% FRB

[a–d] Means sharing different letters in the same column are significantly different ($p < 0.05$)

[A–E] Means sharing different letters in the same row are significantly different ($p < 0.05$)

in low-salt sausage, except for T1 and T2, did not exceed 20 mg% during the 4 weeks storage period ($p < 0.05$).

Changes in TBARS of low-salt frankfurters during refrigerated storage

Lipid oxidation is one of the most important changes during meat products storage and production [26]. It may change the color, aroma, flavor, texture, and nutritive values of meat products [8]. The TBARS values in low-salt frankfurters added with different levels of FRB during refrigerated storage are shown in Table 3. The initial TBARS values for control and all treatments did not significantly ($p > 0.05$) differ. At the end of the storage period (4 weeks), the TBARS values of the sausages added with FRB were effective for inhibiting lipid oxidation, whereas the control and low-salt treatment with ascorbic acid (T1) had the highest TBARS values. Lee and Chin [13] have reported that the TBARS values of ground pork patties added with red beet extracts decreased during refrigerated storage. Previous studies have concluded that fermented vegetable extracts possess the potential as natural agents for food preservation with antioxidant and antimicrobial compounds [9]. This prevention effect of lipid oxidation may be due to the functional ingredients available in FRB. According to Tarladgis et al. [17], the acceptable limits of TBARS value of cooked meat products during storage is 0.5–1.0 mg MD/kg. Kohsaka [27] have reported that malondialdehyde concentration of 0.5 mg MD/kg is a threshold value for rancidity perception by consumers. These results suggested that TBARS values less than 0.5 mg MD/kg does not indicate rancidity. Based on this threshold value and our results were showing that TBARS values of treatments added with FRB did not exceed 0.5 mg MD/kg by the end of the storage period.

Changes in TVC of low-salt frankfurters during refrigerated storage

The effects of the addition of different levels of FRB on microbial contents during refrigerated storage of low-salt frankfurters are shown in Table 4. The initial TVC of frankfurters ranged from 2.40 to 3.28 Log CFU/g. It increased to 6.15–8.88 Log CFU/g after 4 weeks of refrigerated storage. At the end of the storage period (4 weeks), the TVC values of the control and low-salt treatments with T1 (0.05% ascorbic acid) were higher than those of the treatments added with FRB. These results are in agreement with the findings of Jeong et al. [28]. They reported that the microbial population on low-fat sausages added with red beet was less than 2 Log CFU/g during refrigerated storage. Lee and Chin [13] have noted that pork patties with red beet extract added are affected by microbial changes during refrigerated storage. Djeri and Williams [9] have indicated that the anaerobic counts are low when the meat is treated with celery juice powder and cherry juice powder on all storage days. A TVC value of 7 Log CFU/g was established as the upper acceptability limit for processed meat [5, 6].

Presently, the TVC of samples containing FRB were about 6.15–6.82 Log CFU/g at 4 weeks. This decrease in TVC may be due to the antimicrobial compounds of the FRB which inhibits the microbial growth during the entire experimental period.

Changes in color of low-salt frankfurters during refrigerated storage

The lightness (L^*-value), redness (a^*-value), and yellowness (b^*-value) of these low-salt frankfurters formulated with various levels of FRB after refrigerated storage for 4 weeks are shown in Table 5. The color values of low-salt frankfurters may have been influenced by FRB because treatments with higher FRB showed lower lightness and yellowness values but higher redness values. The lightness and yellowness values of all treatments decreased with increasing refrigerated storage, whereas the redness values increased with increased refrigerated storage. This finding agrees with the results of Jeong et al. [28]. They reported that the lightness and yellowness values of low-fat sausages decreased with increasing levels of red beet. In addition, the redness values of sausages increased with increasing red beet levels. They also reported that the yellowness value of low-fat sausages added with red beet decreased with increasing refrigerated storage. Kang and Lee [19] have reported that the level of nitrite added could be reduced by half using red beet for developing the color of sausages. Jeong et al. [28] suggested that the combination of red beet and sodium nitrite might have contributed to the color stability of low-fat smoked sausages during refrigerated storage. These results are in accordance with those of Choi et al. [8]. They have reported that the color of meat products is one of the most important factors considered by consumer when they judge the acceptability of meat products. Discoloring of meat products will have lower consumer acceptability during refrigerated storage, thus causing a major problem for marketing [5]. Therefore, color stability of meat products can be maintained using the antioxidant properties from natural sources such as FRB.

Changes in sensory evaluations of low-salt frankfurters during refrigerated storage

The sensory scores of these low-salt frankfurters with FRB added after storing for 0, 1, 2, 3, and 4 weeks are shown in Table 6. The appearance, color, and juiciness scores of

Table 4 Changes in TVC of low-salt frankfurters formulations with FRB during refrigerated storage for 4 weeks. (Log CFU/g)

	Storage period (weeks)				
	0	1	2	3	4
Control	3.28 ± 0.05^{aE}	3.41 ± 0.15^{bD}	4.00 ± 0.13^{bC}	7.09 ± 0.18^{aA}	8.83 ± 0.12^{aB}
T1	3.11 ± 0.03^{bB}	3.78 ± 0.51^{aB}	4.35 ± 0.06^{aB}	7.82 ± 1.53^{aA}	8.88 ± 0.57^{aB}
T2	2.40 ± 0.07^{dC}	3.09 ± 0.31^{cC}	3.74 ± 0.18^{cB}	5.09 ± 0.60^{bA}	6.82 ± 0.46^{bB}
T3	2.46 ± 0.10^{dD}	3.14 ± 0.18^{cC}	3.21 ± 0.08^{dC}	5.01 ± 0.25^{bA}	6.39 ± 0.12^{bB}
T4	2.75 ± 0.04^{cE}	3.16 ± 0.04^{cC}	2.94 ± 0.14^{eD}	5.02 ± 0.01^{bB}	6.15 ± 0.11^{cA}

All values are mean ± SD of three replicates

Control: frankfurter with 1.5% NaCl, *T1* frankfurter with 1.0% NaCl + 0.05% ascorbic acid, *T2* frankfurter with 1.0% NaCl + 1.0% FRB, *T3* frankfurter with 1.0% NaCl + 3.0% FRB, *T4* frankfurter with 1.0% NaCl + 5.0% FRB

$^{a–e}$ Means sharing different letters in the same column are significantly different ($p < 0.05$)

$^{A–E}$ Means sharing different letters in the same row are significantly different ($p < 0.05$)

Table 5 Changes in color values of low-salt frankfurters formulations with FRB during refrigerated storage for 4 weeks

Color parameters		Storage period (weeks)				
		0	1	2	3	4
L*	Control	73.24 ± 0.25^{aA}	72.79 ± 0.23^{aB}	72.58 ± 0.06^{aB}	71.93 ± 0.38^{aC}	71.27 ± 0.15^{aD}
	T1	72.51 ± 0.25^{bA}	71.40 ± 0.29^{bB}	71.32 ± 0.11^{bB}	71.18 ± 0.04^{bC}	70.07 ± 0.09^{bD}
	T2	70.98 ± 0.15^{cA}	70.93 ± 0.21^{cA}	70.22 ± 0.07^{cB}	70.02 ± 0.43^{cB}	69.91 ± 0.13^{cC}
	T3	70.30 ± 0.08^{dA}	70.25 ± 0.17^{dA}	70.24 ± 0.08^{cA}	69.50 ± 0.36^{dB}	67.53 ± 1.15^{dC}
	T4	68.91 ± 0.09^{eA}	68.07 ± 0.40^{eB}	68.05 ± 0.07^{dB}	67.92 ± 0.09^{eC}	67.51 ± 0.16^{dD}
a*	Control	0.32 ± 0.04^{eC}	0.37 ± 0.08^{dB}	0.38 ± 0.03^{eAB}	0.39 ± 0.02^{eA}	0.40 ± 0.05^{dA}
	T1	-0.48 ± 0.06^{dC}	-0.49 ± 0.07^{dC}	-0.52 ± 0.02^{dB}	0.59 ± 0.08^{dA}	-0.60 ± 0.04^{cA}
	T2	0.75 ± 0.03^{cE}	0.78 ± 0.04^{cD}	0.87 ± 0.02^{cC}	1.03 ± 0.02^{cB}	1.14 ± 0.04^{bA}
	T3	1.04 ± 0.02^{bD}	1.06 ± 0.03^{bD}	1.10 ± 0.02^{bC}	1.91 ± 0.12^{bB}	2.61 ± 0.07^{aA}
	T4	1.66 ± 0.04^{aE}	1.74 ± 0.03^{aD}	1.79 ± 0.03^{aC}	2.05 ± 0.02^{aB}	2.82 ± 0.03^{aA}
b*	Control	15.66 ± 0.28^{aA}	15.62 ± 0.47^{aB}	15.52 ± 0.09^{aA}	15.34 ± 0.09^{aA}	15.06 ± 0.43^{aB}
	T1	15.48 ± 0.36^{bB}	15.42 ± 0.49^{bB}	15.30 ± 0.07^{bA}	15.24 ± 0.29^{bB}	14.83 ± 0.22^{bB}
	T2	15.68 ± 0.12^{aAB}	15.66 ± 0.13^{aAB}	15.58 ± 0.19^{aB}	15.53 ± 0.04^{aA}	15.12 ± 0.19^{aC}
	T3	15.48 ± 0.10^{bA}	15.41 ± 0.13^{bA}	15.32 ± 0.21^{bA}	14.38 ± 0.83^{cB}	14.06 ± 0.26^{cB}
	T4	15.40 ± 0.07^{cA}	15.38 ± 0.09^{cB}	15.17 ± 0.05^{cB}	14.20 ± 0.07^{cC}	14.01 ± 0.15^{cD}

All values are mean ± SD of three replicates

Control: frankfurter with 1.5% NaCl, *T1* frankfurter with 1.0% NaCl + 0.05% ascorbic acid, *T2* frankfurter with 1.0% NaCl + 1.0% FRB, *T3* frankfurter with 1.0% NaCl + 3.0% FRB, *T4* frankfurter with 1.0% NaCl + 5.0% FRB

$^{a–e}$ Means sharing different letters in the same column are significantly different ($p < 0.05$)

$^{A–E}$ Means sharing different letters in the same row are significantly different ($p < 0.05$)

low-salt frankfurter samples with FRB added were slightly lower than those of the control. However, the appearance, color, and juiciness of low-salt frankfurter samples were not significantly ($p > 0.05$) different among all treatments. The appearance, color, and juiciness scores of the control and all treatments slightly decreased with increasing storage period. However, these values were not significantly ($p > 0.05$) different among all treatments except for the color of T3 and the juiciness of T4. The flavor and tenderness scores of all treatments decreased with increasing storage period. The lowest flavor and tenderness scores were found in the treatment with T1 (0.05% ascorbic acid) at the end of storage (4 weeks). The overall acceptability scores seemed to decrease with increasing FRB levels. However, there was no statistical different ($p > 0.05$) value among all treatments except 4 weeks. The overall acceptability scores of all treatments also decreased with increasing storage period. Sensory characteristics are the most important factors in the preparation of meat products and consumer preference. Similar results have been reported by Ha [29] that the sensory characteristics are not affected by the addition of red beet powder during storage.

Table 6 Changes in sensory characteristics of low-salt frankfurters formulations with FRB during refrigerated storage for 4 weeks. (units: score)

	Storage period (weeks)				
	0	1	2	3	4
Appearance					
Control	7.22 ± 1.11	7.25 ± 0.98	7.18 ± 1.32	6.88 ± 1.04	6.68 ± 1.23
T1	7.21 ± 0.84	7.22 ± 1.01	7.20 ± 1.18	6.63 ± 1.08	6.26 ± 0.94
T2	7.24 ± 1.12	7.18 ± 0.71	7.06 ± 0.94	6.61 ± 1.34	6.43 ± 1.14
T3	7.03 ± 0.71	7.14 ± 1.04	6.93 ± 0.87	6.42 ± 1.12	6.17 ± 0.83
T4	7.25 ± 1.32	7.13 ± 0.97	6.81 ± 1.13	6.28 ± 1.04	6.08 ± 0.78
Color					
Control	7.23 ± 1.08	7.16 ± 0.77	6.83 ± 1.03	6.67 ± 0.75	6.17 ± 0.71
T1	7.08 ± 0.71	7.13 ± 0.78	7.08 ± 1.14	6.65 ± 0.83	6.18 ± 0.84
T2	7.32 ± 1.03	7.17 ± 0.84	7.13 ± 1.12	6.83 ± 0.86	6.21 ± 0.84
T3	7.42 ± 0.84^{A}	7.08 ± 1.02^{AB}	7.02 ± 0.84^{AB}	6.92 ± 1.03^{B}	5.63 ± 0.55^{C}
T4	6.84 ± 0.92	7.01 ± 1.07	6.80 ± 1.31	6.64 ± 1.14	6.25 ± 0.84
Flavor					
Control	7.22 ± 0.84^{A}	7.21 ± 1.31^{A}	6.63 ± 1.14^{A}	6.58 ± 0.58^{aA}	5.23 ± 0.84^{abB}
T1	6.84 ± 0.78^{A}	6.62 ± 0.55^{A}	6.82 ± 1.32^{A}	4.89 ± 0.84^{bB}	4.08 ± 1.03^{bB}
T2	7.28 ± 0.83^{A}	7.07 ± 1.22^{AB}	6.92 ± 1.01^{AB}	5.63 ± 1.52^{abB}	5.03 ± 0.73^{aB}
T3	7.42 ± 0.95^{A}	7.23 ± 0.84^{A}	6.87 ± 0.84^{AB}	5.82 ± 0.84^{abBC}	5.02 ± 0.74^{abC}
T4	7.22 ± 0.81^{A}	6.82 ± 1.24^{AB}	6.42 ± 1.03^{ABC}	5.43 ± 0.57^{abBC}	5.01 ± 1.22^{abC}
Tenderness					
Control	7.68 ± 0.64^{A}	7.23 ± 0.47^{A}	6.89 ± 1.12^{AB}	6.82 ± 0.58^{AB}	6.67 ± 1.04^{aB}
T1	7.23 ± 0.84^{A}	7.03 ± 0.71^{A}	6.85 ± 1.05^{AB}	5.84 ± 0.72^{BC}	4.83 ± 0.84^{cC}
T2	7.45 ± 0.58^{A}	7.21 ± 0.84^{A}	7.08 ± 0.83^{A}	5.87 ± 1.12^{B}	6.02 ± 0.71^{aB}
T3	7.06 ± 0.71^{AB}	7.22 ± 0.92^{A}	7.05 ± 0.78^{AB}	6.23 ± 0.82^{BC}	5.63 ± 0.62^{abC}
T4	6.82 ± 0.87^{A}	7.09 ± 0.71^{A}	6.63 ± 1.14^{A}	5.87 ± 1.07^{B}	5.03 ± 0.53^{bB}
Juiciness					
Control	7.45 ± 0.55	7.43 ± 1.13	6.65 ± 1.04	6.09 ± 1.27	6.04 ± 0.89
T1	7.03 ± 0.97	7.01 ± 0.78	7.00 ± 1.02	6.62 ± 1.24	5.48 ± 1.67
T2	7.28 ± 1.18	7.05 ± 1.42	7.03 ± 1.13	6.21 ± 1.59	6.20 ± 0.84
T3	6.87 ± 1.13	6.83 ± 0.84	7.02 ± 1.00	5.87 ± 1.30	5.67 ± 0.55
T4	7.12 ± 1.04^{A}	7.08 ± 1.01^{A}	6.68 ± 1.08^{A}	5.24 ± 0.84^{B}	5.22 ± 0.78^{B}
Overall acceptability					
Control	7.66 ± 0.55^{A}	7.23 ± 0.84^{A}	6.64 ± 0.51^{AB}	5.83 ± 1.03^{B}	5.81 ± 0.84^{aB}
T1	7.08 ± 0.71^{A}	6.85 ± 0.84^{A}	6.62 ± 1.14^{A}	4.61 ± 0.89^{B}	4.43 ± 0.89^{bB}
T2	7.21 ± 0.84^{A}	6.98 ± 0.84^{A}	6.67 ± 0.77^{AB}	5.89 ± 1.16^{B}	6.02 ± 1.21^{aAB}
T3	7.09 ± 1.01^{A}	6.88 ± 0.45^{A}	6.65 ± 0.53^{A}	5.47 ± 1.21^{AB}	5.24 ± 0.84^{abB}
T4	6.65 ± 0.89^{A}	6.81 ± 0.84^{A}	6.28 ± 0.84^{A}	5.08 ± 1.02^{B}	4.22 ± 0.47^{bB}

All values are mean ± SD of three replicates

Control: frankfurter with 1.5% NaCl, *T1* frankfurter with 1.0% NaCl + 0.05% ascorbic acid, *T2* frankfurter with 1.0% NaCl + 1.0% fermented red beet, *T3* frankfurter with 1.0% NaCl + 3.0% fermented red beet, *T4* frankfurter with 1.0% NaCl + 5.0% fermented red beet

[a-c] Means sharing different letters in the same column are significantly different ($p < 0.05$)

[A–C] Means sharing different letters in the same row are significantly different ($p < 0.05$)

Djeri and Williams [9] have reported that the overall acceptability scores for the bologna products preferred by consumers contain the least amount of celery juice powder. Thus, the low-salt frankfurter with added FRB exhibited sensory characteristics similar to those of regular-salt control frankfurters.

In conclusions, we showed that reducing salt levels from 1.5% to 1.0% with the addition of FRB can extend the

shelf-life of reduced-salt frankfurters. Our results demonstrated that FRB could be added to low-salt frankfurters to extend the shelf-life of refrigerated storage.

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Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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