

Effects of Glasswort (*Salicornia herbacea* L.) Hydrates on Quality Characteristics of Reduced-salt, Reduced-fat Frankfurters

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Abstract

This study evaluated the effects of adding glasswort hydrate containing non-meat ingredient (GM, carboxy methyl cellulose; GC, carageenan; GI, isolated soy protein; GS, sodium caseinate) on the quality characteristics of reduced-salt, reduced-fat frankfurters. The pH and color evaluation showed significant differences, depending on the type of glasswort hydrate added ($p < 0.05$). In the raw batters and cooked frankfurters, the addition of glasswort hydrate decreased the redness and increased the yellowness in comparison with frankfurters without glasswort hydrate. The reduction in salt and fat content significantly increased cooking loss and decreased hardness, tenderness and juiciness ($p < 0.05$). Glasswort hydrate containing non-meat ingredient improved cooking loss, water holding capacity, emulsion stability, hardness, and viscosity of reduced-salt, reduced-fat frankfurters. The GM treatment had the highest myofibrillar protein solubility among all treatments, which was associated with emulsion stability and viscosity. The GC treatment had higher values for all texture parameters than the control. In the sensory evaluation, the addition of glasswort hydrate with non-meat ingredient improved tenderness and juiciness of reduced-salt, reduced-fat frankfurters. GM, GC, and GI treatments improved not only the physicochemical properties but also the sensory characteristics of reduced-salt, reduced-fat frankfurters. The results indicated that the use of glasswort hydrate containing non-meat ingredient was improved the quality characteristics of reduced-salt, reduced-fat frankfurters.

Keywords: glasswort, non-meat ingredient, reduced-salt, reduced-fat, frankfurter

Received March 23, 2015; Revised June 8, 2015; Accepted June 11, 2015

Introduction

Recently, consumer interest in health has been increasing, thus, reduction in salt and fat is an important issue in the food industry. Excessive sodium intake from salt contained in processed foods is the primary cause for the rising of blood pressure and cardiovascular disease (Chobanian and Hill, 2000). In addition, high fat diets are related to several diseases, such as obesity, hypertension, cerebral apoplexy, myocardial infarction, diabetics, and coronary heart diseases (Vural and Javidipour, 2002). Consumers may evade meat products because they are generally recognized as having high content of salt and fat.

Salt and fat are consistently used in the manufacture of meat products despite health problems, since they have various functions in the texture and sensory properties of

meat products. Commonly, salt solubilizes myofibrillar proteins (salt soluble proteins) which associate into a gel when heated (Tobin *et al.*, 2012), also positively influences the texture, flavor and shelf life of the final products (Moon *et al.*, 2008). In meat products, fat plays important roles in product quality by stabilizing meat emulsions, reducing cooking loss, and providing juiciness and hardness (Hughes *et al.*, 1997; Pietrasik and Duda, 2000). Hence the food industry is faced with the problems of needing to find for solutions the resulting negative influences on product quality. Several strategies have been proposed to improve the quality properties of reduced-salt, reduced-fat meat products, and most of them consist of the replacement of salt and/or fat with natural sources such as dietary fiber, and non-meat protein (soybean protein, egg protein, etc.). In this study, seaweed, including natural salt component and dietary fiber, along with already known non-meat ingredients were used for the substitution of salt and fat.

Glasswort (*Salicornia herbacea* L.) is a halophyte that grows on the Korean seashore and foreshore. Glasswort

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includes 73.31-74.11% total dietary fiber and 3.40-20.19% NaCl (Han, 2004). In addition, glasswort was found to contain several bioactive compounds contributing to beneficial impacts on human health, and showed antimicrobial, anticancer, and antioxidant activities (Kim and Lee, 2009). Previously, the effects of glasswort on the quality characteristics of various products such as yogurt (Cho *et al.*, 2008), soybean *dasik* (Kim and Hong, 2011), and tofu (Kim *et al.*, 2010) were examined. In meat products, Lim *et al.* (2013) indicated that addition of glasswort to jerky inhibited the growth of microorganisms and lipid oxidation of jerky. In addition, Kim *et al.* (2014a) reported that the addition of glasswort improved the texture properties in reduced-salt frankfurters, suggesting the improvement mainly resulted from dietary fiber and salt present in glasswort. Kim *et al.* (2014b) also indicated that the color characteristics of cooked sausages were greatly affected by the addition of glasswort. Thus, there are limitations for the practical use of glasswort alone as both a salt and fat replacer.

Carboxymethyl cellulose, carrageenan, isolated soy protein, and sodium caseinate have been extensively used in the production of low-salt and/or low-fat meat product. Also, these ingredients successfully improved the functional properties such as water holding capacity, gel strength, and emulsion stability (Ahmad *et al.*, 2010; Defreitas *et al.*, 1997; Youssef *et al.*, 2011). Thus, it is expected that the combination of glasswort and non-meat ingredients would improve the quality characteristics of reduced-salt, reduced-fat meat products.

Therefore, the aim of this study was to investigate the effect of glasswort hydrate containing non-meat ingredient (carboxymethyl cellulose, carrageenan, isolated soy protein, and sodium caseinate) on the physicochemical, textural, and sensory characteristics of reduced-salt, reduced-fat frankfurters.

Materials and Methods

Glasswort hydrates preparation and processing

In this study, glasswort hydrates were used as a simultaneous replacement of salt and fat. Freeze-dried glasswort powder was purchased from a local market. Glasswort powder (4.2% salt content) was washed to reduce salt content in glasswort powder. For washing, glasswort powder and distilled water (20 volumes) were stirred with a magnetic bar for 24 h at room temperature, and then centrifuged at 6,000 *g* for 15 min. After centrifugation,

the supernatant (2.13% salt content) was removed and the residue (1.3% salt content) was taken. The washed glasswort powder was mixed with ice and each non-meat ingredient by using a silent cutter (Nr-963009, Scharfen, Germany). Glasswort hydrate ratio was as follows; non-meat ingredient (carboxymethyl cellulose, carrageenan, isolated soy protein, sodium caseinate):washed glasswort:ice=2:2:6. In preliminary study, when glasswort hydrate mixed difference ratio (non-meat ingredient:washed glasswort:ice=1:1:8), a lot of water and fat separation occurred in complete products. Glasswort hydrates were then individually placed in polyethylene bags and vacuum-packaged using a vacuum packaging system (FJ-500XL, Fujee Tech, Korea) and stored at 4°C until required for product manufacture.

Frankfurters preparation and processing

Fresh pork ham (*M. biceps femoris*, *M. semitendinosus*, *M. semimembranosus*) and pork back fat (moisture 12.61%, fat 85.64%) were purchased from a local processor at 48 h postmortem. All subcutaneous and intramuscular fat and visible connective tissue were removed from fresh ham muscle. Lean meat and back fat were ground through 8 mm plate using a meat grinder (PM-70, Mainca, Spain), separately. The ground tissue was then placed in polyethylene bags, vacuum-packaged using a vacuum packaging system and stored at 0°C until required for product manufacture. Suitable amounts of the muscle and fat were tempered at 4°C for 24 h prior to frankfurter preparation.

Formulations of reduced-salt, reduced-fat frankfurters are given in Table 1. The control formulation was prepared with 1.5% NaCl and 20% back fat. The reduced-salt, reduced-fat treatment (RSF) was made with 1.0% NaCl and 10% back fat (replacement of back fat with only ice). The glasswort hydrate treatments were replaced with 10% glasswort hydrate containing carboxymethyl cellulose (GM), carrageenan (GC), isolated soy protein (GI), sodium caseinate (GS), respectively. For each batch of frankfurters, ground meat, ground fat, ice, and other ingredients were emulsified by using a silent cutter, and the final temperature was below 10°C. After emulsification, meat batters were stuffed into collagen casings (#240, NIPPI Inc., Japan; approximate diameter of 25 mm) using a stuffer (Stuffer IS-8, Italy). The meat batters were then heated at 75±2°C for 30 min in a water bath (Model 10-101, Dae Han Co., Korea) until the core temperature of 75°C. The cooked frankfurters were then cooled and used to analysis physicochemical, textural, and sensory properties.

Table 1. Formulations of reduced-salt, reduced-fat frankfurters with glasswort hydrate

Ingredients (units: %)	Treatments ¹⁾					
	Control	RSF	GM	GC	GI	GS
Pork meat	60	60	60	60	60	60
Ice	20	30	20	20	20	20
Back fat	20	10	10	10	10	10
Glasswort hydrate			10	10	10	10
Total	100	100	100	100	100	100
Sodium chloride (NaCl)	1.5	1.0	1.0	1.0	1.0	1.0
Sodium nitrite (NaNO ₂)	0.012	0.012	0.012	0.012	0.012	0.012
STPP ²⁾	0.3	0.3	0.3	0.3	0.3	0.3
Ascorbic acid	0.05	0.05	0.05	0.05	0.05	0.05
Galric powder	0.3	0.3	0.3	0.3	0.3	0.3
Onion powder	0.3	0.3	0.3	0.3	0.3	0.3
Seasening	0.5	0.5	0.5	0.5	0.5	0.5

¹⁾Control, frankfurter formulated with 1.5% salt and 20% back fat; RSF, reduced salt, reduced-fat frankfurter with 1% salt and 10% back fat; GM, GC, GI and GS, reduced salt, reduced-fat frankfurter with 1% salt, 10% back fat and 10% glasswort hydrate (GM, glasswort hydrate containing carboxy methyl cellulose; GC, glasswort hydrate containing carrageenan; GI, glasswort hydrate containing isolated soy protein; GS, glasswort hydrate containing sodium caseinate).

²⁾STPP: sodium tri-polyphosphate.

Proximate composition

Proximate composition of the frankfurters was determined using AOAC (1995). Moisture content was determined by weight loss after 12 h of drying at 105°C in an oven (SW-90D, Sang Woo Scientific Co., Korea). Fat content was determined by a Soxhlet solvent extraction system (Soxtec Avanti 2050 Auto System, Foss Tecator AB, Sweden) and protein was determined by an automatic Kjeldahl nitrogen analyzer (Kjeltec2300Analyzer Unit, Foss Tecator AB, Sweden). Ash was determined according to AOAC method 923.03.

Salt content

The salt content of frankfurters was determined by homogenized 5 g sample with 20 mL distilled water for 60 s in a homogenizer (Ultra-Turrax T25, Janke and Kunkel, Germany) at 8,000 rpm speed. Then determined with a salimeter (TM-30D, Takemura Electric Works Ltd., Japan).

pH measurement

The pH values of raw batters and cooked frankfurters were measured in a homogenate prepared with 5 g of sample and 20 mL distilled water, using a pH meter (Model 340, Mettler-Toledo GmbH, Switzerland). All determinations were performed in triplicate.

Color measurement

The color of raw batters and cooked frankfurters were measured by the CIE LAB system using a colorimeter (Minolta Chroma meter CR-210, Japan; illuminate C, cal-

ibrated with white plate, L* = +97.83, a* = -0.43, b* = +1.98). All determinations were performed in triplicate, and ten measurements were obtained for each replicate. CIE L* (lightness), CIE a* (redness), and CIE b* (yellowness) values were recorded.

Water holding capacity (WHC)

The water holding capacity (WHC) was measured according to the procedure of Grau and Hamm (1953) with suitable modification. Briefly, the sample (300 mg each) was placed in a filter-press device and compressed for 3 min. The outline area of the expressible juice and the meat film was traced, and the two areas were determined using a compensating polar planimeter (Type KP-21, Japan). WHC was calculated from duplicate samples as a ratio of the meat film area to the total area; hence, a larger value suggests a higher WHC.

$$\text{WHC (\%)} = (\text{meat batter area} / \text{total area}) \times 100$$

Cooking loss

Cooking loss was determined by calculating the weight differences before and after cooking as follows;

$$\text{Cooking loss (\%)} = [(\text{weight of raw batter (g)} - \text{weight of cooked frankfurter (g)}) / \text{weight of raw batter (g)}] \times 100$$

Emulsion stability

The meat batters were analyzed for emulsion stability

using the method of Blouka and Honikel (1992) with suitable modifications. At the middle of a 15 mesh sieve, pre-weighed graduated glass tubes were filled with batter. The glass tubes were closed and heated for 30 min in a boiling water bath to a core temperature of $75\pm 1^\circ\text{C}$. After cooling to approximately $4\pm 1^\circ\text{C}$, to facilitate fat and water layer separation, the fat and water release in the bottom of each tube were measured (Choi *et al.*, 2007).

Water released (%) = [the water layer (mL) / weight of raw meat batter (g)] \times 100

Fat released (%) = [the fat layer (mL) / weight of raw meat batter (g)] \times 100

Protein solubility

Protein solubility was measured according to the procedure of Joo *et al.* (1999) with suitable modification. Sarcoplasmic protein solubility was determined by dissolving 2 g of raw meat emulsion in 20 mL of ice-cold 25 mM potassium phosphate buffer (pH 7.2). The samples and buffer were homogenized on ice with a homogenizer (Model AM-7, Nihonseiki Kaisha Ltd., Japan), and were left to stand on a shaker at 4°C overnight. The mixtures were centrifuged at 6,000 g for 15 min and the protein concentrations of the supernatants determined using the Biuret method (Gornall *et al.*, 1949). Total protein solubility was determined by homogenizing 2 g of meat emulsion in 20 mL of ice-cold 1.1 mol/L potassium iodide in 100 mol/L phosphate buffer (pH 7.2). The procedures for homogenization, shaking, centrifugation, and protein determination were described as above. Myofibrillar protein solubility was obtained by calculating the difference between total and sarcoplasmic protein solubility.

Texture profile analysis (TPA)

Texture measurements in the form of texture profile analysis were performed at room temperature with a texture analyzer (TA-XT2i, Stable Micro Systems, England). Frankfurter samples were taken from the central portion of each frankfurter. Prior to analysis, samples were allowed to equilibrate to room temperature (20°C , 3 h) (Kim *et al.*, 2014a). The conditions of texture analysis were as follows: pre-test speed 2.0 mm/s, post-test speed 5.0 mm/s, maximum load 2 kg, head speed 2.0 mm/s, distance 8.0 mm, force 5 g. The calculation of TPA values was obtained by graphing a curve using force and time plots. Values for hardness (N), springiness, cohesiveness, gumminess (N), and chewiness (N) were determined as described (Bourne,

1978).

Apparent viscosity

The meat batter viscosity was measured in triplicate using a rotational viscometer (HAKKE Viscotester® 500, Thermo Elctron Corporation, Germany) set at 10 rpm. The standard cylinder sensor (SV-2) was positioned in a 25 mL metal cup filled with batter and allowed to rotate under a constant share rate at s^{-1} for 30 s before each reading was taken. Apparent viscosity values in centipoises were obtained. The temperature of each sample at the time ($18\pm 1^\circ\text{C}$) of viscosity testing was also recorded (Choi *et al.*, 2011; Shand, 2000). All determinations were performed in triplicate, and six measurements were obtained for each replicate.

Sensory evaluation

Each frankfurter was evaluated for color, appearance, flavor, tenderness, juiciness, salty taste and overall acceptability. The panel consisted of 10 members from the department of food sciences and biotechnology of animal resources at Konkuk University in Korea. Each member was distributed to the age range of 25 between 30, even up the proportion of experienced men and women. Frankfurter were cooked a center temperature of 75°C and cooled to room temperature at 21°C , then cut into quarters and served to the panelists in random order. Each sample cut into 1 cm length, were served to the panelists in random order. Sensory evaluations were performed by the panelists under fluorescent lighting. Panelists were instructed to cleanse their palates between samples using water. The color (1=extremely undesirable, 10=extremely desirable), appearance (1=extremely undesirable, 10=extremely desirable), flavor (1=extremely undesirable, 10=extremely desirable), tenderness (1=extremely tough, 10=extremely tender), juiciness (1=extremely dry, 10=extremely juicy), salty taste (1=much too weak, 10=much to intense), and overall acceptability (1=extremely undesirable, 10=extremely desirable) of the cooked samples were evaluated using a 10 point descriptive scale.

Statistical analysis

All tests were done at least three times for each experimental condition and mean values were reported. The statistical analysis of all data was performed by SPSS Ver. 18.0 (SPSS Inc., USA). The one-way ANOVA (one-way analysis of variance) and Duncan's multiple range comparison were used to find the level of significant differences ($p<0.05$).

Results and Discussion

Proximate composition and physicochemical properties

Proximate composition and salt content of reduced-salt, reduced-fat frankfurters are given in Table 2. Reduced-salt, reduced-fat frankfurters with glasswort hydrate had higher moisture content than control ($p<0.05$). Dietary fiber in glasswort and non-meat ingredients might be associated with increased moisture content due to an improvement of water retention within the meat emulsion system. Protein content of GI and GS treatments were higher than other treatments ($p<0.05$), because isolated soy protein and sodium caseinate were protein based ingredients (Jiménez-Colmenero *et al.*, 2005; Nishinari *et al.*, 2014). Ash content of reduced-salt, reduced-fat frankfurters with glasswort hydrate was higher than RSF treatment ($p<0.05$) due to minerals in glasswort. Commonly, as the mineral content increases, ash content increases. As expected, control presented the highest fat and salt content among all treatments ($p<0.05$). Salt content of reduced-salt, reduced fat frankfurters with glasswort hydrate ranged from 1.4%

to 1.21%, and there was no significant difference in compared to RSF treatment ($p>0.05$).

The pH, lightness (L^* -value), redness (a^* -value), and yellowness (b^* -value) values of raw batters and cooked frankfurters are given Table 3. The pH of raw meat batters ranged from 5.97 to 6.02, and that of cooked frankfurters ranged from 6.08 to 6.15. Except for the GM treatment, the pH values of the raw meat batters and cooked frankfurters prepared with glasswort hydrate were higher than those of the control and RSF treatments ($p<0.05$). Kim *et al.* (2014a) noted that the pH value of reduced sodium frankfurters with glasswort powder were similar to the control. This result might be affected by non-meat ingredients added. In previous studies, the addition of non-meat ingredients (carrageenan, isolated soy protein, and sodium caseinate) increased pH of meat products (Bloukas *et al.*, 1996; Chin *et al.*, 2000; Kilic, 2003).

The addition of glasswort hydrate affected the color attributes (L^* , a^* , and b^*) of reduced-salt, reduced-fat frankfurters. The lightness and redness values of reduced-salt, reduced-fat frankfurters with glasswort hydrate were significantly lower than the control and RSF treatments in

Table 2. Proximate composition (g/100 g) and salt content (%) of reduced-salt, reduced-fat frankfurters with glasswort hydrate

Parameters	Control ¹⁾	RSF	GM	GC	GI	GS
Moisture	61.97±0.63 ^b	68.34±0.25 ^a	68.57±1.07 ^a	68.55±1.46 ^a	68.31±0.23 ^a	68.76±0.72 ^a
Protein	14.71±0.85 ^{bc}	14.08±0.18 ^c	14.34±1.45 ^c	14.72±0.93 ^{bc}	16.29±1.07 ^{ab}	16.83±1.09 ^a
Fat	20.38±1.88 ^a	14.21±0.62 ^b	12.15±1.25 ^b	12.73±2.23 ^b	12.92±2.01 ^b	12.88±1.94 ^b
Ash	2.36±0.04 ^b	1.89±0.11 ^d	2.04±0.05 ^c	2.86±0.12 ^a	2.03±0.07 ^c	2.10±0.11 ^c
Salt content	1.73±0.08 ^a	1.09±0.01 ^b	1.17±0.04 ^b	1.21±0.01 ^b	1.20±0.08 ^b	1.14±0.08 ^b

All values are mean±standard deviation of three replicates.

^{a-d}Means within a row with different letters are significantly different ($p<0.05$).

¹⁾Control, frankfurter formulated with 1.5% salt and 20% back fat; RSF, reduced salt, reduced-fat frankfurter with 1% salt and 10% back fat; GM, GC, GI and GS, reduced salt, reduced-fat frankfurter with 1% salt, 10% back fat and 10% glasswort hydrate (GM, glasswort hydrate containing carboxy methyl cellulose; GC, glasswort hydrate containing carrageenan; GI, glasswort hydrate containing isolated soy protein; GS, glasswort hydrate containing sodium caseinate).

Table 3. pH and color parameters of reduced-salt, reduced-fat frankfurters with glasswort hydrate

Parameters	Control ¹⁾	RSF	GM	GC	GI	GS	
Raw batters	pH	5.98±0.01 ^b	5.97±0.03 ^b	5.98±0.01 ^b	6.02±0.01 ^a	6.02±0.01 ^a	6.01±0.01 ^a
	L^* -value	67.20±0.84 ^a	55.61±1.30 ^c	63.38±0.71 ^b	62.54±0.90 ^b	61.19±1.09 ^c	59.33±1.26 ^d
	a^* -value	12.35±0.35 ^a	11.69±0.50 ^b	8.82±0.27 ^d	9.24±0.42 ^c	9.04±0.24 ^{cd}	9.07±0.20 ^{cd}
	b^* -value	18.09±0.69 ^b	14.01±0.51 ^c	18.45±0.39 ^b	20.53±0.54 ^a	18.33±0.44 ^b	18.29±0.37 ^b
Cooked frankfurters	pH	6.09±0.01 ^c	6.08±0.01 ^c	6.10±0.01 ^b	6.15±0.01 ^a	6.15±0.01 ^a	6.15±0.01 ^a
	L^* -value	71.32±0.44 ^a	69.78±0.45 ^{bc}	70.98±0.49 ^a	69.00±0.75 ^d	69.84±0.27 ^b	69.37±0.42 ^c
	a^* -value	10.21±0.20 ^b	10.79±0.33 ^a	6.87±0.16 ^d	7.27±0.14 ^c	6.90±0.16 ^d	7.24±0.13 ^c
	b^* -value	11.03±0.21 ^d	10.77±0.36 ^c	12.76±0.28 ^c	14.38±0.25 ^a	12.81±0.26 ^c	13.11±0.25 ^b

All values are mean±standard deviation of three replicates.

^{a-c}Means within a row with different letters are significantly different ($p<0.05$).

¹⁾Control, frankfurter formulated with 1.5% salt and 20% back fat; RSF, reduced salt, reduced-fat frankfurter with 1% salt and 10% back fat; GM, GC, GI and GS, reduced salt, reduced-fat frankfurter with 1% salt, 10% back fat and 10% glasswort hydrate (GM, glasswort hydrate containing carboxy methyl cellulose; GC, glasswort hydrate containing carrageenan; GI, glasswort hydrate containing isolated soy protein; GS, glasswort hydrate containing sodium caseinate).

both raw batters and cooked frankfurters ($p < 0.05$), on the other hand the yellowness values presented the opposite results. Similar trends in the color values were observed in studies by Kim *et al.* (2014b). They reported that the addition of glasswort powder in reduced-salt frankfurters decreased the yellowness value, and increased the lightness and redness values. Also, Cofrades *et al.* (2008) found similar results when added edible seaweeds. RSF treatment had lower lightness and yellowness values compared to control ($p < 0.05$), due to the salt and fat content. In previous studies, the color attributes were affected depending on salt and fat content (Carballo *et al.*, 1996; Fernández-López *et al.*, 2004).

Water holding capacity (WHC), cooking loss, and emulsion stability

The WHC, cooking loss, and emulsion stability of reduced-salt, reduced-fat frankfurters are given in Table 4. The WHC of the control was higher than that of the other treatments ($p < 0.05$). However, glasswort hydrate improved the WHC of reduced-salt, reduced-fat frankfurters in comparison with RSF treatment. According to Desmond (2006), a wide variety of ingredients such as functional proteins, fibers, hydrocolloids and starches enhance the binding of meat pieces in restructured or reformed meat products, and increase the WHC of the finished products. Several studies, the non-meat ingredients when used this study improved the WHC of low-salt/fat products (Bloukas *et al.*, 1996; Jiménez-Colmenero *et al.*, 2010; Zayas, 1985).

In RSF treatment, a significant increase of cooking loss was observed in comparison with control ($p < 0.05$). Generally, the reduction of salt and fat affected cooking loss, due to reduced water binding and lower concentration of the protein which forms the gel/emulsion matrix (Jiménez-

Comenero *et al.*, 1996). Reduced-salt, reduced-fat frankfurters with glasswort hydrate presented a decrease of cooking loss in comparison with RSF treatment ($p < 0.05$). Kim *et al.* (2014a) reported that increase in the level of glasswort added to reduced-salt frankfurter led to the improvement of cooking yield. They suggested that such result was due to improvement of the ionic strength and water binding capacity by the salt and dietary fiber of glasswort. In addition, carrageenans, isolated soy proteins, and sodium caseinates are also known to increase the yield in meat products (Bloukas *et al.*, 1996; Kassem and Emara, 2010; Kezban and Kolsarici, 2003; Youssef *et al.*, 2011).

For the emulsion stability, there was no significant difference in fat released between the control and other treatments ($p > 0.05$). However, there was a significant difference in the water released ($p < 0.05$). The control had lower water released than the other treatments ($p < 0.05$), on the other hand, RSF treatment had the highest water released ($p < 0.05$). Although reduced-salt, reduced-fat frankfurters with glasswort hydrate had higher water released than the control, they were improved in comparison to RSF treatment. The results might be affected dietary fiber in glasswort and non-meat ingredients. Cofrades *et al.* (2008) reported that low-salt (0.5% salt) emulsion meat systems with edible seaweeds had greater emulsion stability than the control (2% salt) despite having less added salt. They suggested that two of the chemical component of seaweeds, dietary fiber and protein, may influence the emulsion stability of meat systems. Previous studies have reported that the addition of various types of dietary fiber to meat products, such as wheat (Choi *et al.*, 2007), hazelnut pellicle (Turhan *et al.*, 2005), and rice bran (Choi *et al.*, 2011) help to improve the emulsion stability and rheological properties. Also, there was study about the effects of non-meat ingredients on the emulsion stability of meat

Table 4. Effects of glasswort hydrate on water holding capacity, cooking loss, and emulsion stability of reduced-salt, reduced-fat frankfurters

Parameters	Control ¹⁾	RSF	GM	GC	GI	GS
WHC (%)	96.61±0.58 ^a	82.96±2.21 ^c	94.81±1.76 ^b	94.71±2.09 ^b	95.99±1.17 ^{ab}	95.71±1.03 ^{ab}
Cooking loss (%)	5.89±0.18 ^d	8.30±0.88 ^a	7.00±1.14 ^b	6.24±0.14 ^{cd}	6.66±0.17 ^{bc}	6.52±0.29 ^{bcd}
Emulsion stability						
Total released (%)	4.01±1.04 ^d	21.01±0.33 ^a	5.82±1.16 ^{cd}	5.65±1.63 ^{cd}	8.19±2.00 ^{bc}	9.33±0.41 ^b
Water released (%)	3.64±1.04 ^d	20.65±0.33 ^a	5.43±1.15 ^{cd}	5.34±1.56 ^{cd}	7.80±2.01 ^{bc}	8.94±0.41 ^b
Fat released (%)	0.36±0.01 ^{ab}	0.36±0.01 ^{ab}	0.39±0.01 ^a	0.31±0.07 ^b	0.39±0.01 ^a	0.39±0.01 ^a

All values are mean±standard deviation of three replicates.

^{a-d}Means within a row with different letters are significantly different ($p < 0.05$).

¹⁾Control, frankfurter formulated with 1.5% salt and 20% back fat; RSF, reduced salt, reduced-fat frankfurter with 1% salt and 10% back fat; GM, GC, GI and GS, reduced salt, reduced-fat frankfurter with 1% salt, 10% back fat and 10% glasswort hydrate (GM, glasswort hydrate containing carboxy methyl cellulose; GC, glasswort hydrate containing carrageenan; GI, glasswort hydrate containing isolated soy protein; GS, glasswort hydrate containing sodium caseinate).

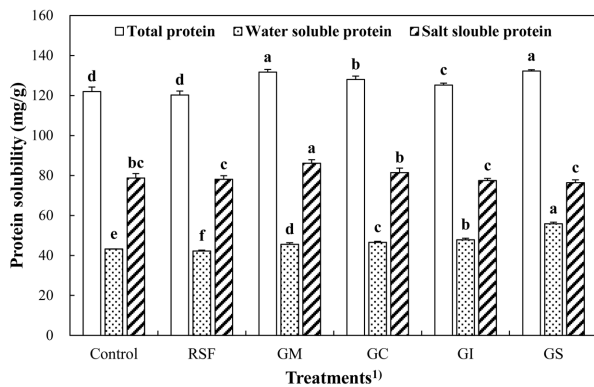


Fig. 1. Effects of glasswort hydrate on protein solubility of reduced-salt, reduced-fat frankfurters. ¹⁾Control, frankfurter formulated with 1.5% salt and 20% back fat; RSF, reduced salt, reduced-fat frankfurter with 1% salt and 10% back fat; GM, GC, GI and GS, reduced salt, reduced-fat frankfurter with 1% salt, 10% back fat and 10% glasswort hydrate (GM, glasswort hydrate containing carboxy methyl cellulose; GC, glasswort hydrate containing carrageenan; GI, glasswort hydrate containing isolated soy protein; GS, glasswort hydrate containing sodium caseinate). ^{a-f}Means in the treatments with different letters are significantly different ($p < 0.05$).

products (Schuh *et al.*, 2013). The combination of glasswort and non-meat ingredients affected to the processing yield, due to improvement of the water binding ability.

Protein solubility

The solubility of total, sarcoplasmic, and myofibrillar proteins in reduced-salt, reduced-fat frankfurters are presented in Fig. 1. Protein solubility is an important factor related to emulsion formation. In particular, myofibrillar proteins (salt soluble proteins) are the most functional proteins in processed meat product, and are comprised primarily of myosin and actin (Smith, 1988). Myosin is responsible for most of the gelation and water holding prop-

erties of processed meat, whereas the other myofibrillar proteins influence the behavior of myosin (Smith, 1988; Wang and Smith, 1994). Generally, the solubility of myofibrillar proteins is affected by salt content (Swift and Sulzbacher, 1963). The myofibrillar protein solubility of control was higher than that of RSF treatment ($p < 0.05$). Total protein solubility of frankfurters with glasswort hydrate was higher than the control and RSF treatments ($p < 0.05$). According to Kim *et al.* (2014b), the addition of glasswort to reduced-salt meat batters increased total and myofibrillar protein solubility, which was suggested to be affected by the pH, ionic strength, type of salt, and mineral concentrations. In myofibrillar proteins solubility, GM and GC treatments were higher than control ($p < 0.05$). In the study of Choi *et al.* (2011), the increase of rice bran fiber contributed to improvement of protein solubility. In contrast, Kim *et al.* (2013) indicated that the increase of brewer's spent grain dietary fiber contributed to a decline of protein solubility. Protein solubility was affected by the addition of ingredients. Thus, the results of this study might be attributed to the characteristics of each non-meat ingredient and glasswort such as pH, solubility, and dispersibility.

Texture profile analysis (TPA)

Texture profile analysis of reduced-salt, reduced-fat frankfurters is presented in Table 5. Reduced-salt, reduced-fat frankfurters with glasswort hydrates improved texture properties, despite a decrease of hardness caused by the reduction of salt and fat. According to Hsu and Sun (2006), the reduction of fat caused decreased hardness, chewiness, and gumminess in meat products. GC treatment had higher values than control in all of the texture parameters. This result might be attributed to the synergy effect of glasswort and carrageenan, in that carrageenan is a soluble fiber that can form a gel network like glasswort. Sim-

Table 5. Effects of glasswort hydrate on texture profile analysis (TPA) of reduced-salt, reduced-fat frankfurters

Parameters	Control ¹⁾	RSF	GM	GC	GI	GS
Hardness (<i>N</i>)	4.23±0.21 ^b	3.10±0.11 ^d	3.82±0.17 ^c	5.36±0.40 ^a	4.19±0.13 ^b	3.75±0.10 ^c
Springiness	0.86±0.01	0.87±0.03	0.88±0.01	0.87±0.04	0.88±0.01	0.87±0.02
Cohesiveness	0.41±0.01 ^c	0.44±0.02 ^{ab}	0.43±0.01 ^{bc}	0.46±0.03 ^a	0.45±0.02 ^{ab}	0.45±0.02 ^{ab}
Gumminess (<i>N</i>)	1.74±0.08 ^c	1.36±0.08 ^d	1.65±0.07 ^c	2.47±0.22 ^a	1.89±0.05 ^b	1.67±0.08 ^c
Chewiness (<i>N</i>)	1.50±0.06 ^c	1.19±0.07 ^d	1.45±0.07 ^c	2.14±0.29 ^a	1.67±0.06 ^b	1.46±0.09 ^c

All values are mean±standard deviation of three replicates.

^{a-d}Means within a row with different letters are significantly different ($p < 0.05$).

¹⁾Control, frankfurter formulated with 1.5% salt and 20% back fat; RSF, reduced salt, reduced-fat frankfurter with 1% salt and 10% back fat; GM, GC, GI and GS, reduced salt, reduced-fat frankfurter with 1% salt, 10% back fat and 10% glasswort hydrate (GM, glasswort hydrate containing carboxy methyl cellulose; GC, glasswort hydrate containing carrageenan; GI, glasswort hydrate containing isolated soy protein; GS, glasswort hydrate containing sodium caseinate).

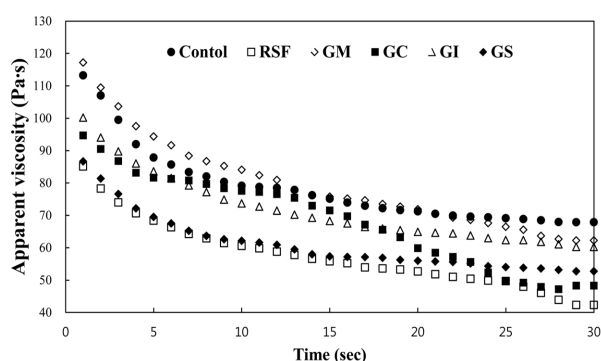


Fig. 2. Effects of glasswort hydrate on apparent viscosity of reduced-salt, reduced-fat frankfurters. ¹⁾Control, frankfurter formulated with 1.5% salt and 20% back fat; RSF, reduced salt, reduced-fat frankfurter with 1% salt and 10% back fat; GM, GC, GI and GS, reduced salt, reduced-fat frankfurter with 1% salt, 10% back fat and 10% glasswort hydrate (GM, glasswort hydrate containing carboxy methyl cellulose; GC, glasswort hydrate containing carrageenan; GI, glasswort hydrate containing isolated soy protein; GS, glasswort hydrate containing sodium caseinate).

ilar trends were observed in the study by Jiménez-Colmenero *et al.* (2010). They reported that reduced/low-fat, low-salt frankfurters with konjac and seaweed had similar hardness as that of the control (21.1% fat and 2% salt). Kim *et al.* (2014a) reported that the addition of glasswort powder increased hardness in reduced-salt frankfurters. In addition, previous studies reported that carrageenan and isolated soy protein increased hardness in sausages (García-García and Totosaus, 2008; Matulis *et al.*, 1995). There was no significant differences in springiness of the frankfurters ($p>0.05$).

Apparent viscosity

The addition of glasswort hydrate obviously affected

the apparent viscosity of reduced-salt, reduced-fat meat batters (Fig. 2). All samples showed a decreased apparent viscosity of meat batter with increase in the rotation time. The apparent viscosity of RSF treatment was lower than the other treatments. Except for GS treatment, the apparent viscosity of other treatments with glasswort hydrate was higher than RSF treatment. In GM treatment, which showed the highest myofibrillar protein solubility, the highest maximum apparent viscosity was observed. Farouk *et al.* (2002) reported that protein solubility can influence textural and rheological properties. According to Shand (2000) and Turgut *et al.* (1981) showed that there is a high correlation between emulsion viscosity and emulsion stability in meat emulsion systems. In this study, emulsion stability of GI and GS treatments was lower than the other glasswort treatments, and similar trends were observed for viscosity.

Sensory evaluation

The sensory traits of reduced-salt, reduced-fat frankfurters with glasswort hydrate are shown in Table 6. The mean values of color, appearance, flavor, tenderness, juiciness and salty taste were evaluated to determine the overall acceptability. In color scores, all frankfurters with glasswort hydrate had lower scores than RSF treatment ($p<0.05$). There was no significant difference in flavor, appearance, and salty taste scores ($p>0.05$). These results were due to unfamiliarity with the green color and unique flavor of glasswort. Although the tenderness and juiciness scores of frankfurters with glasswort hydrates were improved in compared to RSF treatment ($p<0.05$). These results were associated with the improvement of cooking loss, WHC, emulsion stability, and texture properties by the addition of glasswort hydrate in reduced-salt, reduced-fat frankfurters. In overall acceptability scores, frankfurt-

Table 6. Effects of glasswort hydrate on sensory properties of reduced-salt, reduced-fat frankfurters

Parameters	Control ¹⁾	RSF	GM	GC	GI	GS
Color	8.30±0.67 ^a	8.20±0.63 ^a	7.00±0.67 ^b	7.20±0.42 ^b	7.20±0.42 ^b	7.20±0.42 ^b
Appearance	8.10±0.74	8.00±0.82	8.00±0.82	7.90±0.74	8.00±0.82	7.80±0.79
Flavor	8.13±0.64 ^a	7.38±0.74 ^b	7.25±0.46 ^b	7.13±0.83 ^b	7.13±0.64 ^b	7.00±0.76 ^b
Tenderness	8.10±0.74 ^a	6.60±0.84 ^b	7.60±0.84 ^a	7.50±0.71 ^a	7.50±1.08 ^a	7.50±0.97 ^a
Juiciness	8.20±0.79 ^a	6.60±0.97 ^b	7.50±1.08 ^{ab}	7.50±1.18 ^{ab}	7.40±0.97 ^{ab}	7.50±0.53 ^{ab}
Salty taste	7.20±1.48 ^a	5.90±1.60 ^b	5.30±1.25 ^b	5.00±0.82 ^b	5.50±1.08 ^b	5.40±0.84 ^b
Overall acceptability	8.13±0.64 ^a	7.25±0.71 ^b	7.38±0.52 ^b	7.38±0.92 ^b	7.50±0.53 ^b	7.13±0.64 ^b

All values are mean±standard deviation of three replicates.

^{a,b}Means within a row with different letters are significantly different ($p<0.05$).

¹⁾Control, frankfurter formulated with 1.5% salt and 20% back fat; RSF, reduced salt, reduced-fat frankfurter with 1% salt and 10% back fat; GM, GC, GI and GS, reduced salt, reduced-fat frankfurter with 1% salt, 10% back fat and 10% glasswort hydrate (GM, glasswort hydrate containing carboxy methyl cellulose; GC, glasswort hydrate containing carrageenan; GI, glasswort hydrate containing isolated soy protein; GS, glasswort hydrate containing sodium caseinate).

ers with glasswort hydrate and RSF treatment had no significant difference ($p>0.05$), but GM, GC, and GI treatments were higher than RSF treatment. Tobin *et al.* (2012) found that lower salt levels resulted in darker/deeper color than higher salt levels. They also found high positive correlation between juiciness and higher levels of salt and fat. Jimenez-Colmenero *et al.* (2010) reported that frankfurters with added seaweed gained lower scores than control in overall acceptability, otherwise received similar scores in texture acceptability as the control. On sensory evaluation, the addition of glasswort hydrate to reduced-salt, reduced-fat frankfurters improved texture properties such as tenderness and juiciness, but it is necessary to promote understanding about the color and flavor characteristics of glasswort and non-meat ingredients.

Conclusions

The use of glasswort hydrate containing non-meat ingredient improved the cooking loss, WHC, hardness, emulsion stability, and viscosity of reduced-salt, reduced-fat frankfurters. GM, GC, and GI treatments had improvement of not only the physicochemical properties but also the sensory attributes related to the texture (tenderness and juiciness) of reduced-salt, reduced-fat frankfurters. Thus, the use of glasswort hydrate containing non-meat ingredient was improved the quality characteristics of reduced-salt, reduced-fat frankfurters.

Acknowledgements

The authors were supported by the Brain Korea 21 Plus (BK 21 PLUS) Project from Ministry of Education and Human Resources Development. This research was supported Technology Development Program (PJ009237042 014) for Rural Development Administration, Republic of Korea.

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