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Potential Use of Glasswort Powder as a Salt Replacer for the Production of Healthier Dry-Cured Ham Products

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Abstract

Seong P.-N., Seo H.-W., Cho S.-H., Kim Y.-S., Kang S.-M., Kim J.-H., Kang G.-H., Park B.-Y., Moon S.-S., Hoa V.-B. (2017): Potential use of glasswort powder as a salt replacer for the production of healthier dry-cured ham products. Czech J. Food Sci., 35: 149–159.

The World Health Organization has recommended reducing sodium intake as well as its content in food products to reduce the risk of hypertension and cardiovascular diseases. Glasswort (*Salicornia herbacea* L.), a halophyte naturally growing in the salt marshes over the world, has widely been used as a salt replacer in the production of many food types. In this study, the impacts of replacement of 50% NaCl with 20 and 40 g/kg of glasswort powder on the quality characteristics of four different dry-cured pork cuts including Bulgi (semimembranosus, semitendinosus, and adduct muscles), Seolgit (biceps femoris muscle), Dogani (quadriceps femoris muscle), and Boseop (middle gluteal and gracilis muscles) were investigated. Our results revealed that the replacement of 50% salt with glasswort powder did not cause any defects of technological quality, colour, texture, and sensory quality of the finished products. As expected, the replacement of 50% salt with glasswort powder (20 g/kg) resulted in a reduction of approximately 37.30, 23.80, 33.33, and 30.89% in Bulgi, Seolgit, Dogani, and Boseop products, respectively. The present work demonstrates that the glasswort powder represents a potentially natural ingredient to be used as a salt replacer for the production of healthier dry-cured hams with lowered sodium content.

Keywords: technological quality; salt replacement; sodium content

Dry-cured ham is one of the popular cured meat products with typical sensory characteristics (Jimenez-Colmenero *et al.* 2010; Toldrá & Aristoy 2010). Untill now, various types of dry-cured hams have been commercially produced and available on the markets with high commercial value (Resano *et al.* 2007). The dry-cured meat products as a whole have high storage stability due to their typical physicochemical properties such as low moisture and pH, and high salt content (Papadima & Bloukas 1999). Compared to the added salt levels of about 1.5% in other meat products such as frankfurter or Vienna sausage types (Choe *et al.* 2013; Seong *et al.* 2015) the levels of salt added to the dry-cured meat products are often higher, about 3–9% (w/w) due to the microbiological safety and 'shelf-stable' issues (Gil *et al.* 1999; Andres *et al.* 2004; Uguz *et al.* 2011; Seong *et al.* 2014). For centuries, salt has been used for the preservation of meat products and is one of the most widely used ingredients in meat product processing not only due to its contribution to desirable flavour, texture, and shelf-life of the products but also the cheapest cost (Man 2007). Despite its essential functions in producing

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high-quality and safe meat products, however, the intake of sodium from processed foods has been linked to the increased risk of hypertension, stroke, and cardiovascular diseases (Matthews & Strong 2005; Strazzullo *et al.* 2009). Hypertension is one of the major causes of death in developed countries (Merz *et al.* 2009).

A clear relationship between hypertension and excessive sodium intake has been found (Stamler *et al.* 1996). Therefore, the World Health Organization (WHO) has recommended reducing the intake of sodium content as well as this content in food products (Asaria *et al.* 2007). So far, there has been an increasing interest in reducing the added sodium level in processed meat products by replacing salt (NaCl) with salt replacers such as soy sauce (Kremer *et al.* 2009; Mcgough *et al.* 2012), or KCl, $CaCl_2$, and $MgCl_2$ (Gimeno *et al.* 1999; Costa-Corredor *et al.* 2009; Armenteros *et al.* 2012; De Ciriano *et al.* 2013).

Glasswort (*Salicornia herbacea L.)* is a halophyte naturally growing in the salt marshes in Korea as well as other areas in the world such as Eurasia, North America, and Middle East (Rhee *et al.* 2009). For the past decades, the glasswort has been processed into powder or extract form which are widely used as a seasoning or salt replacer in making many food types such as steamed rice cake, tofu, low-salt fermented cabbage (*kimchi*), cooked sausages, frankfurters, and beef jerky (Kim 2013; Lim *et al.* 2013; Kim *et al.* 2014a, b). The glasswort powder contains 12.53% moisture, 1.66% protein, 0.84% fat, 8.92% sodium, 0.96% potassium, 0.57% magnesium, and 0.57% calcium (Han *et al.* 2003; Kim *et al.* 2014a). Especially, the glasswort has also been proved to have bioactivities such as antioxidant, anti-hypertension, anti-diabetes, and anti-cancer effects (Jo *et al.* 2002).

Practically, the manufacture of dry-cured ham products is time-consuming, approximately from 280 to 660 days because these products are usually made from whole legs of pigs with average weights of about 6–12 kg (Andres *et al.* 2004; Cilla *et al.* 2005; Costa-Corredor *et al.* 2009; Armenteros *et al.* 2012; Seong *et al.* 2014). Despite the dry-cured hams are often made with high salt levels as mentioned above, as well as the negative effects of the excessive sodium intake on health has been widely reported, however, there are still limited studies focusing on reducing the added NaCl content in these product types (Costa-Corredor *et al.* 2009; Armenteros *et al.* 2012). Moreover, these previous studies only focused on replacing salt with synthetic salts such as KCl, $CaCl_2$, and $MgCl_2$ while the replacement with these substitutes such as KCl resulted in increased bitterness and decreased saltiness has been reported (Gou *et al.* 1996; Desmond 2006). The glasswort is a cheap and abundant ingredient which has been used as salt substitutes in making many food types. However, no attention has been paid to the utilisation and efficacy of this ingredient in dry-cured ham products. In the present study, instead of using whole thighs, four different cuts with their corresponding muscles obtained from each pork ham were used for the production of dry-cured cut products, and to evaluate the effect of replacing 50% salt with different levels of glasswort powder on the technological and sensory characteristics of the products.

MATERIAL AND METHODS

Material. Deboned hams with an average weight of 8.0 ± 0.2 kg collected at 24 h post-mortem from a commercial slaughterhouse (Korea) were used. The ingredients such as onion powder, ginger powder, garlic powder, and black pepper (Beksul, Korea), NaCl (Hanju, Korea), and $NaNO_2$ (Sigma Chemical, USA) were used for the processing of dry-cured hams. Glasswort powder (GP) was purchased from Changcho Foods Com. Cheonnam (Korea).

Pork cut preparation and processing of dry-cured cuts. The levels of glasswort powder used as a salt replacer in the present work were based on the levels used for other meat products (e.g., beef jerky or cooked sausages) reported in previous studies (Lim *et al.* 2013; Kim *et al.* 2014a) with suitable modification for the cured ham products.

Four separated pork cuts with their corresponding muscles named: Bulgi (semimembranosus, semitendinosus, and adductor muscles), Seolgit (biceps femoris muscle), Dogani (quadriceps femoris muscle), and Boseop (middle gluteal and gracilis muscles) fabricated from each ham according to the Standard for Retail Cut Trading (MFDS 1996) were used for the production of dry-cured products in the present study (Figure 1A). All the cuts were made with the same levels of ingredients: 0.1% black pepper, 0.5% onion powder, 0.5% ginger powder, 0.5% garlic powder, 0.02% $NaNO_2$, except salt (NaCl), and glasswort powder (GP) contents that differed between the control and treatments (Table 1). Particularly, for each cut type (n = 30), ten cuts added 2% (corresponding

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Table 1. Processing formulations of dry-cured pork cut products

Ingredients	Control 0% GP	Replacement	
		2% GP	4% GP
NaCl	2	1	1
Glasswort powder	0	2	4
$NaNO_2$	0.02	0.02	0.02
Black pepper	0.1	0.1	0.1
Onion powder	0.5	0.5	0.5
Garlic powder	0.5	0.5	0.5
Ginner powder	0.5	0.5	0.5

GP – glasswort powder; 2% GP – 20 g GP/kg; 4% GP – 40 g GP/kg

to 100%) NaCl without GP were served as controls while in the remaining cuts 50% NaCl (a half of 2%) salt were replaced with 2% (20 g/kg) GP (2% GP, n = 10) or 4% (40 g/kg) GP (4% GP, n = 10). All dry-cured cuts were processed on the same day in a pilot plant. Salting was performed by rubbing the ingredient mixture on the surfaces. The salted cuts were kept at 4°C for 7 days to allow the seasonings to penetrate (post-salting without casing). Afterwards, the cuts were stuffed into collagen casings (Naturin Viscofan, Spain), tightened, and held at 4°C for 30 days at relative humidity of 85% (post-salting with casing). Eventually, they were hung up and ripened at 12°C and 65% relative humidity for 150 days (Figures 1B and 1C). At the end of the ripening period (187 days) when the products achieved a water activity of about

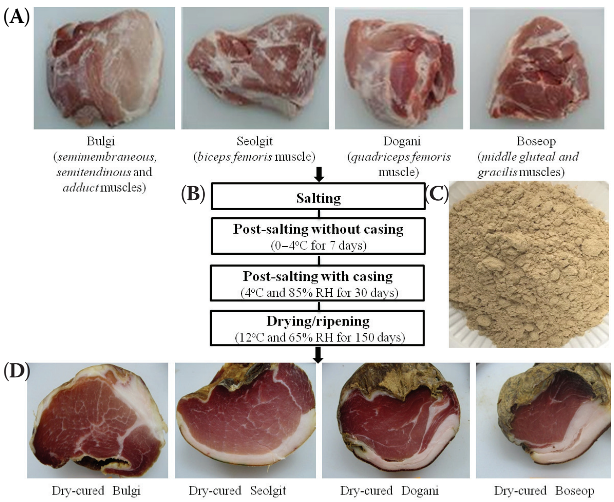

Figure 1. The used raw cut types with their muscles (**A**), processing conditions (**B**), glasswort powder used (salt replacer) (**C**), and the cross-section of dry-cured pork cuts (**D**) at the end of ripening (187 days)

0.85–0.87, the samples were collected, removed from outer casing, and immediately used for the analyses (Figures 1D). All the samples were then assessed for yield, proximate composition, technological quality traits (water activity and pH), colour, texture, and sensory quality, except for the protein, saturated fat, calorie, cholesterol, and sodium contents which were determined only in the control samples and those in which salt was replaced with 2% GP.

Proximate composition. Moisture, fat, protein, and calorie contents were analysed using the method of the Association of Official Analytical Chemists (Methods AOAC 986.15.). Particularly, the moisture and fat contents were determined using a moisture and fat analyser (SMART Trac; CEM Corp., USA) while the nitrogen content was determined using a nitrogen analyser (rapid N cube, Elementar, Germany) and then converted into protein content using the N × 6.25 equation. To determine calories, the sample was homogenised in a blender; then the homogenate was used for the measurement of calorie content using a calorimeter (model 6400; Parr Instrument, USA). Calories were expressed as kcal/100 g of the sample.

pH and water activity. The pH values of samples were determined in triplicates using a pH meter (Model 340; Mettler-Toledo GmbH, Switzerland) that was calibrated with 3 different standard pH solutions (4.0, 7.0, and 9.25). The pH was measured after homogenising 3 g of each sample with 27 ml of distilled water for 30 s using a homogeniser. Water activity (a_w) of the fermented sausages was determined at 25°C with a Novasina measuring instrument, AW SPRINT-TH 300 model (Pfaffikon, Switzerland). Calibration was done using several saturated solutions of known a_w.

Colour measurement. Colour was determined at 3 defined areas on the cut surface of each sample using a Minolta Chroma Meter (CR-400 model, 8 mm measuring aperture; Illuminant condition: CIE: C, D65; CIE: 2° Standard Observer. Minolta Camera Ltd., Japan) that was standardised with a white plate (Y = 86.3, X = 0.3165, and y = 0.3242). Colour was expressed according to the Commission Internationale de l'Eclairage (CIE) system and reported as CIE L^* (lightness), CIE a^* (redness), CIE b^* (yellowness), chroma, and hue angle (h°). Chroma and hue angle were calculated as $(a^{*2} + b^{*2})^{0.5}$ and $\tan^{-1}(b^*/a^*)$, respectively.

Instrumental texture analysis. The texture properties were analysed using a puncture probe (7 mm diameter) attached to a texture Analyser (Model 4465;

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Instron Corp., United Kingdom). For texture analysis, the samples from the control or treatments were cut into 2.5-cm thick pieces which were then axially compressed twice until reaching each time 80% of their initial height. The speed of the load cell was set at 120 mm/min and the following parameters were calculated: hardness (N), cohesiveness (kg × mm), and springiness.

Cholesterol, saturated fat, and sodium contents. The cholesterol, saturated fat, and sodium contents were determined using the methods standardised by the Ministry of Food and Drug Safety of Korea (MFDS 2014). The levels of the examined contents were calculated into milligrams or grams in 100 g sample.

Sensory evaluation. For sensory evaluation, 5 randomly selected samples from each product type treated with each level (0, 2, and 4%) of GP were used. The panellists with an average age of 25–35 years were the members of the National Institute of Animal Science, Jeonju, Korea. Each sample was cut into 0.3 cm thick pieces, placed onto dishes and coded with random numbers. A total of 360 sensory samples were randomly allotted in 5 sessions; each session had 12 panellists and each panellist evaluated 6 samples. The panellists were seated in private seats under fluorescent lighting and were served the sensory samples in a random manner. Five major sensory traits including colour, flavour, taste, and overall acceptability were used and the samples were then evaluated for the aforementioned traits using a 7-point scale (1 = extremely undesirable, 7 = extremely desirable) as described by Meilgaard *et al*. (1991). The panellists were asked to refresh their palate with drinking distilled water and salt-free crackers between samples. All sensory sessions were carried out in the sensory panel booth room equipped with white lighting at a constant temperature of about 20°C.

Statistical analysis. The data were subjected to statistical analysis using the Statistical Analysis System package (SAS 9.1.3., 2007). Data were analysed by the General Linear Model procedure considering replacement with glasswort powder level and product type as the main effects. Means were compared using Duncan's Multiple Range Test, with a significance of $P < 0.05$. Principal component analysis (PCA) was determined to explore relationships between multiple variables of products added with/without glasswort powder.

For sensory evaluation data, all panellists were included in sensory evaluation portion of analysis. In the statistical model, the panellist and evaluation session were considered as random effects while the treatment and product type were considered as fixed effects. The analysis was then done using GLM of SAS as described above.

RESULTS AND DISCUSSION

Effect on proximate compositions (yield, moisture, and fat) and technological quality traits (pH and water activity). Proximate composition and technological quality traits of dry-cured pork cuts produced with replacement of 50% NaCl with different levels of GP are presented in Table 2. Regarding the moisture, no significant differences occurred between the control samples and those replaced with GP within each dry-cured cut type ($P > 0.05$). However, comparing the moisture content between the cuts shows a statistical difference; a higher level in Seolgit compared to those of the other remaining cuts ($P < 0.05$). This could be related to the differences in moisture contents between the raw cuts used. The moisture levels (47.73–57.57%) in all dry-cured cuts in the present study were almost similar to the levels (50.94–53.99%) reported for the dry-cured ham ripened for 280 days (Armenteros *et al*. 2012). For the fat content, the replacement with GP did not affect its levels in the majority of studied products ($P > 0.05$). Similarly, the yields of products made by replacing salt with GP were not significantly different from the control within each cut type ($P > 0.05$). However, comparing the yields between the cuts shows significantly ($P < 0.05$) higher levels in Seolgit at all replaced levels in comparison with the other remaining cuts. These results could be explained by the higher moisture content in this cut as shown above.

The pH values ranged between the control and GP treatments for the Bulgi, Seolgit, Dogani, and Boseop products from 5.68–5.99, 5.63–5.78, 5.71–5.86, and 5.64–5.91 in the present study. In which, the replacement with GP resulted in lower pH values compared with the control; this could be due to a higher level of lactic acid produced in these treated samples. In general, the pH values in all samples in the present study were much lower than the values (6.03–6.72) reported for the dry-cured hams made from whole legs (Arnau *et al*. 2003; Seong *et al*. 2014). It is well known that the shelf-life of many food products is affected by a number of factors such as pH condition; the lower the pH, the higher the shelf-life stability.

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Table 2. Proximate composition and technological quality traits of dry-cured pork cuts replaced with different levels of glasswort powder (GP) at the end of ripening

Item	Replaced level (% GP)	Product type			
		Bulgi	Seolgit	Dogani	Boseop
Moisture (%)	0	49.97 ± 1.65^{b}	57.57 ± 1.31^{a}	53.35 ± 2.21^{ab}	48.86 ± 1.53^{b}
	2	51.93 ± 1.28^{ab}	54.12 ± 2.77^{a}	55.70 ± 1.78^{a}	47.73 ± 0.29^{b}
	4	50.38 ± 1.09	52.16 ± 2.18	53.78 ± 2.39	51.42 ± 3.23
Fat (%)	0	8.36 ± 0.14^{a}	5.48 ± 0.20b^{B}	5.44 ± 0.51^{b}	6.90 ± 0.61^{ab}
	2	5.91 ± 0.80	6.90 ± 0.68^{AB}	4.55 ± 0.39	5.86 ± 0.44
	4	6.86 ± 1.03^{ab}	8.46 ± 0.85^{aA}	4.56 ± 0.28^{b}	5.03 ± 0.73^{b}
Yield (%)	0	57.67 ± 0.55^{b}	65.81 ± 2.16^{a}	57.58 ± 1.69^{b}	60.77 ± 1.72^{ab}
	2	55.79 ± 1.03^{b}	66.43 ± 1.86^{a}	57.82 ± 1.72^{b}	59.45 ± 2.55^{b}
	4	55.02 ± 1.75^{b}	65.83 ± 1.07^{a}	55.04 ± 0.64^{b}	57.60 ± 2.13^{b}
pH	0	5.99 ± 0.06^{aA}	5.67 ± 0.06^{b}	5.86 ± 0.05^{ab}	5.91 ± 0.14^{aA}
	2	5.69 ± 0.05^{B}	5.63 ± 0.04	5.71 ± 0.09	5.64 ± 0.02^{AB}
	4	5.68 ± 0.05^{B}	5.78 ± 0.05	5.83 ± 0.07	5.68 ± 0.06^{B}
Water activity (a_w)	0	0.86 ± 0.01^{b}	0.88 ± 0.01^{a}	0.86 ± 0.01^{b}	0.84 ± 0.01^{c}
	2	0.87 ± 0.01^{a}	0.86 ± 0.01^{a}	0.87 ± 0.01^{a}	0.83 ± 0.01^{b}
	4	0.87 ± 0.01^{a}	0.87 ± 0.01^{ab}	0.86 ± 0.01^{ab}	0.84 ± 0.01^{c}

$^{a–c}$different letters in the same row are significantly different (P < 0.05); $^{A–C}$different letters in the same column within each item are significantly different (P < 0.05)

Regarding the water activity (a_w), it is well known that the shelf-life stability of food products usually increases with decreasing a_w, whereas high a_w (e.g., around 0.95) can form an ideal medium for bacterial growth on the surface that influences the microbiological stability (Fernandez-Salguero *et al.* 1993). The a_w values in all samples replaced with GP were not significantly different from the control within each product studied (P > 0.05), suggesting that the partial replacement of salt with GP did not affect the rate of water activity reduction. Comparing the a_w values between the cut products shows significantly lower values in Boseop at all replaced levels as compared with those of the other products (P < 0.05). The a_w values in all samples made with/without GP in the present study were generally lower than the values (0.89–0.91) reported for dry-cured ham ripened for 413 days (Seong *et al.* 2014), but almost similar to the values (0.86–0.88) reported of dry-cured ham ripened for 415 days (Andres *et al.* 2005). The contrasting results could be due to the difference between the studies in the sizes of raw materials or ripening conditions used. From these obtained results and previous reports it could be said that the separation of whole raw hams into individual cuts could help quickly obtain the desired technological quality traits (e.g., pH, moisture, and water activity), which partly reduces the processing time as well as the production cost of products in comparison with the use of whole hams. Neither did the replacement of 50% salt with GP seem to cause any alterations in the technological quality of products.

Effect of salt replacement on colour traits. The colour traits of dry-cured cuts as affected by the replacement with GP are presented in Table 3. It was observed that the replacement of NaCl with GP did not cause any alterations in the colour parameters such as L^* (lightness), a^* (redness), b^*(yellowness), chroma, and hue angle in any studied cut, except for Dogani which showed decreased redness and chroma values as the GP level increased. Comparing the individual colour traits between the products made with/without GP shows that there were significant differences in the following values: Bulgi and Seolgit had higher L^* values compared to those of the Dogani and Boseop products, similarly Bulgi had lower a^* values but had higher b^* values compared to the other products (P < 0.05). These results could be related to variations in the natural colour characteristics among the raw cuts used. Our results agree well with those of Andres *et al.* (2005), who showed differences in the colour traits between the muscles

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Table 3. Colour traits of dry-cured pork cuts replaced with different levels of glasswort powder (GP) at the end of ripening

Item	Replaced level (% GP)	Product type			
		Bulgi	Seolgit	Dogani	Boseop
CIE L^* (lightness)	0	43.92 ± 3.46[a]	44.84 ± 0.39[a]	36.45 ± 0.92[b]	39.85 ± 1.56[ab]
	2	44.95 ± 2.94[a]	42.02 ± 3.21[ab]	38.96 ± 0.78[b]	38.59 ± 2.27[b]
	4	38.66 ± 1.84	42.25 ± 2.04	39.08 ± 1.07	38.97 ± 2.13
CIE a^* (redness)	0	11.04 ± 0.33[b]	13.55 ± 0.29[a]	12.90 ± 1.03[aA]	11.61 ± 0.46[ab]
	2	10.51 ± 1.07[b]	12.69 ± 0.24[a]	12.32 ± 0.92[abAB]	12.15 ± 0.45[ab]
	4	12.16 ± 0.41	12.12 ± 0.29	10.38 ± 0.82[B]	10.68 ± 0.47
CIE b^* (yellowness)	0	9.97 ± 1.07[a]	8.73 ± 0.13[ab]	7.43 ± 0.48[b]	8.95 ± 0.68[ab]
	2	9.60 ± 0.71	8.45 ± 0.44	8.32 ± 0.41	9.37 ± 0.80
	4	9.82 ± 0.69[a]	8.88 ± 0.71[ab]	7.33 ± 0.22[b]	8.78 ± 0.46[ab]
Chroma	0	15.00 ± 0.48	16.12 ± 0.35	14.91 ± 1.12[A]	14.74 ± 0.41
	2	14.33 ± 0.93	15.26 ± 0.40	14.88 ± 0.94[AB]	15.41 ± 0.49
	4	15.70 ± 0.30[a]	15.08 ± 0.58[ab]	12.74 ± 0.68[cB]	13.88 ± 0.17[bc]
Hue angle (h°)	0	42.08 ± 3.17[a]	32.85 ± 0.16[ab]	30.02 ± 0.57[b]	37.58 ± 2.83[a]
	2	42.69 ± 3.55[a]	33.61 ± 1.14[b]	34.28 ± 1.23[b]	37.51 ± 2.83[ab]
	4	38.88 ± 2.70	36.07 ± 1.87	35.64 ± 2.37[b]	39.41 ± 2.63

[a–c]different letters in the same row are significantly different ($P < 0.05$); [A–B]different letters in the same column within each item are significantly different ($P < 0.05$)

of 415 days-ripened hams. Colour is the single most important factor of meat products that affects the consumer purchasing decision. When compared to the a^* values (8.7–11) in dry-cured hams ripened for 415 days (Andres *et al.* 2005), all the dry-cured cuts made with or without salt replacement in the present study generally had similar or higher values. Cilla *et al.* (2005) and Seong *et al.* (2014) also reported similar a^* values for the semimembranosus and biceps femoris muscles of dry-cured hams ripened for 413–660 days.

Effect of salt replacement on instrumental texture. The texture profile of cut products replaced with different GP levels is presented in Table 4. Regarding hardness, the replacement with GP levels did not alter the hardness values of any cut studied, except

Table 4. Texture traits of dry-cured pork cuts replaced with different levels of glasswort powder (GP) at the end of ripening

Item	Replaced level (% GP)	Product type			
		Bulgi	Seolgit	Dogani	Boseop
Hardness (N)	0	23.63 ± 1.66	34.81 ± 1.32	27.26 ± 1.51[A]	27.16 ± 1.30
	2	24.02 ± 0.90[b]	38.24 ± 2.01[a]	16.08 ± 0.89[bAB]	35.50 ± 1.82[a]
	4	23.63 ± 1.11[b]	39.03 ± 1.15[a]	15.78 ± 0.68[bB]	24.51 ± 0.78[b]
Cohesiveness	0	2.26 ± 0.36	2.89 ± 0.41	2.25 ± 0.14	2.26 ± 0.34
	2	2.58 ± 2.47[ab]	2.85 ± 0.25[a]	2.11 ± 0.06[ab]	1.76 ± 0.47[b]
	4	2.07 ± 0.35[ab]	2.57 ± 0.09[a]	2.01 ± 0.19[ab]	1.73 ± 0.30[b]
Springiness (mm)	0	16.52 ± 2.21[a]	10.96 ± 1.75[bB]	17.12 ± 0.53[a]	16.02 ± 0.77[a]
	2	15.65 ± 0.91	17.67 ± 0.33[A]	15.25 ± 1.29	17.98 ± 1.57
	4	14.91 ± 0.73	15.46 ± 0.90[A]	16.54 ± 0.85	18.07 ± 0.81

[a–b]different letters in the same row are significantly different ($P < 0.05$); [A–B]different letters in the same column within each item are significantly different ($P < 0.05$)

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for Dogani which showed lower values compared to the control. Similarly, the replacement with GP did not affect the cohesiveness and springiness values for any of the studied products, only except for Seolgit which showed increased springiness values in samples replaced with GP. Regarding the effect of salt replacement with other substitutes on the texture of meat products, Collins (1997) reported that the reduction of salt content generally leads to unexpected textural properties of finished meat products. Similarly, Gimeno *et al.* (1999) found that partial replacement of NaCl with KCl and $CaCl_2$ resulted in decreases in hardness and cohesiveness of fermented sausages. Whereas, Alino *et al.* (2009) reported that replacement of 70% NaCl with KCl significantly increased hardness and chewiness of dry-cured loins. Thus, from the obtained results it could be said that the replacement of NaCl with GP apparently had a minor impact on the textural properties of most dry-cured cuts studied.

Effect of salt replacement on calories, saturated fat, protein, cholesterol, and sodium. In the present study, the foresaid contents were determined only in control samples and those replaced with 2% GP, and the obtained results are presented in Table 5. Regarding the calorie and saturated fat contents, no significant differences occurred between the control and treated samples within any cut product ($P > 0.05$). However, dry-cured Bulgi had higher calorie content compared to the other remaining cuts such as Seolgit or Boseop ($P < 0.05$), probably due to the higher saturated fat content in this product since the fat is one of the richest sources of energy. The variations in the saturated fat levels among the raw cuts used could be due to differences in the content. Similarly, the replacement with 2% GP did not affect the protein content within any product studied. The protein contents ranging between the products from 32.33 g/100 g to 38.85 g/100 g in the present study were lower than the levels (40–42 g/100 g) reported for dry-cured hams in literature (Marusic *et al.* 2011; Seong *et al.* 2014). The contrasting results could be explained by lower moisture contents in samples in these studies.

Regarding the sodium (Na) content, the replacement of 50% NaCl with 20 g GP/kg resulted in a reduction of approximately 0.88, 0.35, 0.68, and 0.76 g/100 g sodium corresponding to 37.30, 23.80, 33.33, and 30.89% in Bulgi, Seolgit, Dogani, and Boseop products, respectively, in relation to the controls. The Boseop product contained a significantly higher sodium level in both control and treated samples compared to the other remaining products, indicating that the sodium content from the added salt and/or GP penetrated into these products at a faster rate. The variations in sodium contents among the cuts used could be related to differences in natural physicochemical properties which affected the penetration rate of salt into the muscles. When compared to the sodium levels of approximately 1.8 g/100 g reported for most types of dry-cured hams (Jimenez-Colmenero *et al.* 2010), all the products replaced with 2% GP had lower levels.

Sodium is an essential nutrient found in salt and many foods, and our bodies need a small amount of

Table 5. Chemical composition of dry-cured pork cuts replaced with different levels of glasswort powder (GP) at the end of ripening

Item	Replaced level (% GP)	Product type			
		Bulgi	Seolgit	Dogani	Boseop
Saturated fat (g/100 g)	0	3.40 ± 1.05	2.70 ± 0.28	3.38 ± 0.06	2.81 ± 0.18
	2	3.50 ± 0.17^{a}	2.80 ± 0.21^{b}	3.13 ± 0.31^{b}	3.10 ± 0.56^{b}
Calories (Kcal/100 g)	0	232.40 ± 23.03^{a}	195.23 ± 15.61^{ab}	229.50 ± 20.16^{ab}	192.28 ± 8.31^{b}
	2	254.50 ± 20.05^{a}	211.32 ± 7.39^{b}	217.68 ± 17.90^{ab}	232.95 ± 7.31^{ab}
Protein (g/100 g)	0	36.25 ± 1.83	32.33 ± 1.92	37.95 ± 3.33	33.43 ± 0.45
	2	32.45 ± 2.60^{b}	34.67 ± 1.50^{ab}	36.15 ± 1.99^{ab}	38.85 ± 1.01^{a}
Na (g/100 g)	0	1.86 ± 0.04^{bcA}	1.47 ± 0.07^{cA}	2.04 ± 0.07^{bA}	2.46 ± 0.12^{aA}
	2	0.98 ± 0.09^{cB}	1.12 ± 0.08^{bcB}	1.36 ± 0.05^{bB}	1.7 ± 0.15^{aB}
Cholesterol (mg/100 g)	0	169.70 ± 4.84	174.93 ± 3.69^{B}	166.43 ± 12.37	155.35 ± 4.94
	2	154.83 ± 6.65	146.8 ± 9.44^{A}	157.98 ± 11.88	146.75 ± 6.94

$^{a–c}$different letters in the same row are significantly different ($P < 0.05$); $^{A–B}$different letters in the same column within each item are significantly different ($P < 0.05$)

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sodium to be healthy, but the intake of too much salt can lead to high blood pressure which is a major risk factor for stroke, heart disease, and kidney disease (Antonios & MacGregor 1997; Matthews & Strong 2005; Asaria *et al.* 2007; Strazzullo *et al.* 2009). According to recommendations of the U.S. Food and Drug Association (2012), for optimal heart health, adult people should eat no more than 2.3 g of sodium per day. This level is associated with a reduction in blood pressure, which in turn reduces the risk of heart disease and stroke. Therefore, according to this recommended level (2.3 g) for the control cut products (without salt replacement), adults could consume a maximum amount of 123.65, 156.46, 112.74, and 93.49 g of Bulgi, Seolgit, Dogani, and Boseop per day, respectively. While for the products with replaced salt, adult people could consume higher amounts such as 234.69, 205.35, 169.11, and 135.39 g per day for Bulgi, Seolgit, Dogani, and Boseop, respectively. Thus, it can be said that the replacement with GP not only makes the products healthier but also increases the consumed amounts of the products.

Cholesterol has long been known as the cause of cardiovascular diseases, high blood pressure, and mortality in the world (Tanasescu *et al.* 2004). The outcome of our analysis showed that the replacement with 20 g GP/kg generally resulted in reductions of cholesterol contents in all cut products studied, with reductions of approximately 14.87, 28.05, 8.45, and 8.60 mg/100 g in Bulgi, Seolgit, Dogani, and Boseop, respectively. However, statistically significant ($P < 0.05$) differences were observed only in dry-cured Seolgit with a reduction of approximately 16.03% in relation to the control. Regarding this, the glasswort has been proved to have biological activities and is used to treat diseases such as hypertension, diabetes, and cancer (Jo *et al.* 2002; Han *et al.* 2003). In the present work, we assessed the effect of replacement with glasswort powder on cholesterol content in dry-cured ham, and the exact mechanism underlying the cholesterol-reducing effect of the added GP still remains unknown. Therefore, further study is needed to elucidate the mechanism underlying this phenomenon.

Effect of salt replacement on sensory characteristics. The results of sensory evaluation of the products produced with/without replacement of salt with GP are presented in Table 6. Regarding colour, the panellists gave little higher colour scores to the samples replaced with GP than for the control samples in all products, but not significantly different ($P > 0.05$). Significant ($P < 0.05$) differences in colour scores were found only between the Boseop and Bulgi products which were both replaced with the same GP level (2%). Similar to the colour, no differences ($P > 0.05$) in flavour scores were found between the control and treated samples in any cut

Table 6. Sensory traits of dry-cured pork cuts replaced with different levels of glasswort powder (GP) at the end of ripening

Item	Replaced level (%GP)	Product type			
		Bulgi	Seolgit	Dogani	Boseop
Colour	0	4.96 ± 0.54	5.13 ± 0.12	4.96 ± 0.35	5.08 ± 0.39
	2	4.79 ± 0.27^{b}	5.50 ± 0.10^{a}	5.17 ± 0.18^{ab}	5.63 ± 0.23^{a}
	4	5.13 ± 0.05	5.33 ± 0.14	5.38 ± 0.16	5.46 ± 0.33
Flavour	0	5.25 ± 0.11^{ab}	4.83 ± 0.14^{b}	5.08 ± 5.21^{ab}	5.50 ± 0.35^{a}
	2	4.83 ± 0.18	5.33 ± 0.18	5.38 ± 0.17	5.44 ± 0.48
	4	4.67 ± 0.28^{b}	5.54 ± 0.17^{a}	5.08 ± 0.16^{a}	4.96 ± 0.08^{ab}
Taste	0	5.75 ± 0.17^{aA}	5.25 ± 0.14^{ab}	5.13 ± 0.14^{bB}	5.46 ± 0.28^{ab}
	2	4.96 ± 0.17^{bB}	5.67 ± 0.15^{a}	5.50 ± 0.15^{abAB}	5.54 ± 0.40^{ab}
	4	5.17 ± 0.26^{bAB}	5.67 ± 0.18^{ab}	5.83 ± 0.23^{aA}	5.75 ± 0.05^{ab}
Acceptability	0	5.67 ± 0.29	5.13 ± 0.08	5.42 ± 0.20	5.67 ± 0.34
	2	5.13 ± 0.18^{b}	5.71 ± 0.10^{ab}	5.85 ± 0.15^{a}	5.88 ± 0.44^{a}
	4	5.17 ± 0.20^{b}	5.79 ± 0.26^{ab}	5.71 ± 0.21^{ab}	5.88 ± 0.08^{a}

$^{a–c}$different letters in the same row are significantly different ($P < 0.05$); $^{A–B}$different letters in the same column within each item are significantly different ($P < 0.05$)

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product studied. However, comparing the flavour scores between the cut products shows differences; lower scores for Bulgi (replaced with 4% GP) compared to the other remaining products such as Seolgit and Dogani (replaced with the same GP level) ($P < 0.05$). Lim *et al*. (2013) reported higher flavour scores for beef jerky made with 0.5–1% GP compared to that made without GP. The replacement with GP had minor effects on the taste of the products, since similar scores were found for both the control and treated samples in all the products ($P < 0.05$), except Dogani which showed higher ($P < 0.05$) scores in the treated samples compared to the control. Lastly, no statistical differences in acceptability scores were reported for the control and treated samples in any cut product ($P < 0.05$), however the panellists generally gave higher scores to treated samples than to the control. Furthermore, comparing the acceptability scores between the products shows some differences; higher scores in the Dogani and Boseop products (replaced with 2 or 4% GP) compared to the other remaining products ($P < 0.05$). Regarding the effect of salt replacement on the sensory quality of dry-cured ham, Armenteros *et al*. (2012) reported no differences in sensory trait scores between the control and that made by replacing 50% NaCl with 50% KCl.

Principal component analysis (PCA). The results of the first three principal components (PCs) are plotted in Figures 2A and 2B. The PCA showed that about 69.76 and 44.19% of the variability were explained by the first two PCs and the third PC, respectively. PC1 was positively related to calories and saturated fat whereas it was inversely related to Na, cholesterol, and protein. Dry-cured Bulgi with 0 and 2% GP was on the positive PC1 axis, while the other remaining dry-cured cuts were on the negative PC1 axis. PC2 was positively related to all variables including calories, saturated fat, protein, cholesterol, and Na. Dry-cured cuts from Dogani-0% GP, Bulgi-0% GP, and Boseop-2% GP treatments were on the positive PC2 axis. Finally, PC3 was positively related to saturated fat, cholesterol, and Na, and inversely related to calories and protein. The dry-cured cuts from Seolgit-0% GP, Boseop-0% GP, Bulgi-0% and Bulgi-2% GP, and Dogani-0% GP treatments were on the positive PC3 axis. PC1 shows a clear difference between the dry-cured Bulgi cuts replaced with/without glasswort powder and the others as it obtained higher scores for calories and saturated fat. While PC2 allows the separation of the treatments according to cholesterol and Na scores, discriminating products made without glasswort powder (control) from the other treatments with glasswort powder. Similar to the PC2, PC3 also shows a clear difference between the dry-cured cuts made without glasswort powder (control) and those made with glasswort, as it obtained higher scores for cholesterol and Na. These differences were also observed in the results for chemical compositions (Table 5).

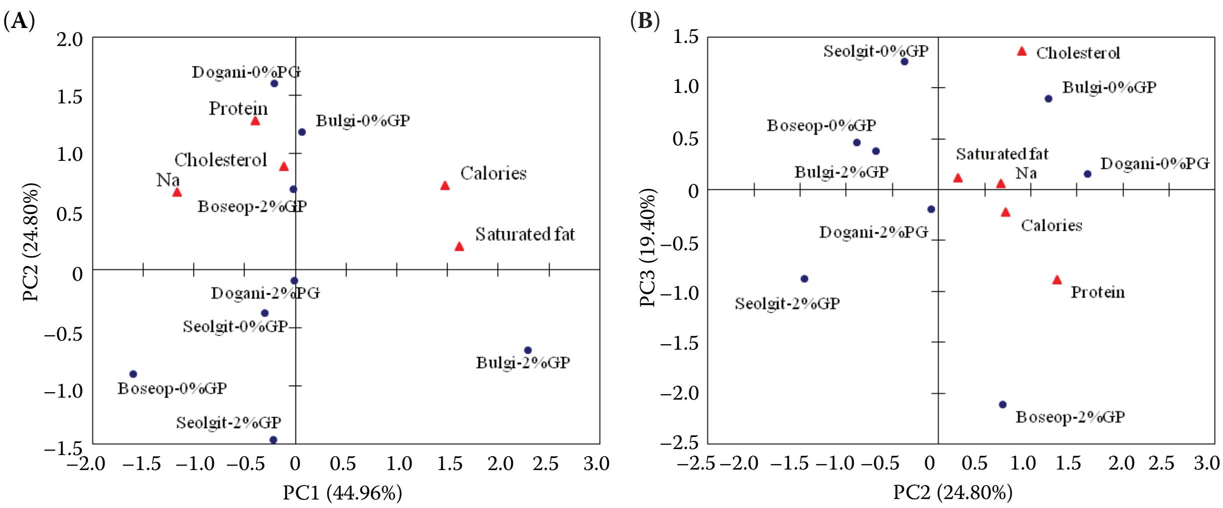

Figure 2. Principal component (PC) analysis for some chemical compositions of dry-cured pork cuts in which 50% salt was replaced with 2% glasswort powder (GP): (**A**) projection of variables and fermented ham treatments in the plane defined by PC1 and PC2; (**B**) projection in the plane defined by PC2 and PC3; Bulgi-0% GP, replaced with 0% GP; Bulgi-0% GP, replaced with 2% GP; Seolgit-0% G, replaced with 0% GP; Seolgit-2% G, replaced with 2% GP; Dogani-0% PG, replaced with 0% GP; Dogani-2% PG, replaced with 2% GP; Boseop-0% GP, replaced with 0% GP; Boseop-2% GP, replaced with 2% GP

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CONCLUSION

In the present study, four different dry-cured pork cut products with lowered sodium content were successfully produced by replacing 50% of NaCl with different levels of glasswort powder. The total processing time of the cuts was 187 days, which was much shorter compared to the time required for the whole dry-cured ham production reported in literature but it still ensured the final quality of the products. The replacement of NaCl with glasswort powder did not cause any alterations in technological quality, colour, texture, and sensory properties whereas it significantly reduced sodium content in the products. Results from the present study therefore suggest that the glasswort powder represents a natural ingredient that could be used as a salt replacer and the replacement of 50% of NaCl by 20 or 40 g of glasswort powder/kg is a way to produce healthier dry-cured hams with lowered sodium content. Insights into the impact of replacement with glasswort powder on the shelf-life stability (e.g., microbiological index) as well as the mechanisms underlying the cholesterol lowering of products will be investigated in a future study.

References

Alino M., Grau R., Toldra F., Blesa E., Pagan M.J., Barat J.M. (2009): Influence of sodium replacement on physicochemical properties of dry-cured loin. Meat Science, 83: 423–430.

Andres A.I., Cava R., Ventanas J., Thovar V., Ruiz J. (2004): Sensory characteristics of Iberian ham: Influence of salt content and processing conditions. Meat Science, 68: 45–51.

Andres A.I., Ventanas S., Ventanas J., Cava R., Ruiz J. (2005): Physicochemical changes throughout the ripening of dry cured hams with different salt content and processing conditions. European Journal of Food Research and Technology, 221: 30–35.

Antonios T.F.T., MacGregor G.A. (1997): Scientific basis for reducing salt (sodium) content in food products. In: Pearson A.M., Dutson T.R. (eds): Production and Processing of Healthy Meat, Poultry and Fish Products: Advances in Meat Research Series. London, Chapman and Hall: 84–100.

Armenteros M., Aristoy M.C., Barat J.M., Toldrá F. (2012): Biochemical and sensory changes in dry-cured ham salted with partial replacements of NaCl by other chloride salts. Meat Science, 90: 361–367.

Arnau J., Gou P., Comaposada J. (2003): Effect of the relative humidity of drying air during the resting period on the composition and appearance of dry-cured ham surface. Meat Science, 65: 1275–1280.

Asaria P., Chisholm D., Mathers C., Ezzati M., Beaglehole R. (2007): Chronic disease prevention: health effects and financial costs of strategies to reduce salt intake and control tobacco use. Lancet, 370: 2044–2053.

Choe J.H., Kim H.Y., Lee J.M., Kim Y.J., Kim C.J. (2013): Quality of frankfurter-type sausages with added pig skin and wheat fiber mixture as fat replacers. Meat Science, 93: 849–854.

Cilla I., Martinez L., Beltran J.A., Roncales P. (2005): Factors affecting acceptability of dry-cured ham throughout extended maturation under "bodega" conditions. Meat Science, 69: 789–795.

Collins J.E. (1997): Reducing salt (sodium) levels in processed meat, poultry and fish products. In: Pearson A.M., Dutson T.R. (eds): Production and Processing of Healthy Meat, Poultry and Fish Products: Advances in Meat Research Series. London, Chapman and Hall: 282–297.

Costa-Corredor A., Serra X., Arnau J., Gou P. (2009): Reduction of NaCl content in restructured dry-cured hams: Post-resting temperature and drying level effects on physicochemical and sensory parameters. Meat Science, 83: 390–397.

de Ciriano G.M., Berasategi L., Navarro-Blasco I., Astiasaran L., Ansorena D. (2013): Reduction of sodium and increment of calcium and ω-3 polyunsaturated fatty acids in dry fermented sausages effects on the mineral content, lipid profile and sensory quality. Journal of the Science and Food Agriculture, 93: 876–881.

Desmond E. (2006): Reducing salt: A challenge for the meat industry. Meat Science, 74: 188–196.

Fernandez-Salguero J., Gomez, G., Camona M.A. (1993): Water activity in selected high moisture foods. Journal of Food Composition and Analysis, 3: 364–369.

Gil M., Guerrero L., Sarraga C. (1999): The effect of meat quality, salt and ageing time on biochemical parameters of dry-cured Longissimus dorsi muscle. Meat Science, 51: 329–337.

Gimeno O., Astiasarán I., Bello J. (1999): Influence of partial replacement of NaCl with KCl and $CaCl_2$ on texture and color of dry fermented sausages. Journal of Agricultural and Food Chemistry, 47: 873–877.

Gou P., Guerrero L., Gelabert J., Arnau J. (1996): Potassium chloride, potassium lactate and glycine as sodium chloride substitutes in fermented sausages and in dry-cured pork loin. Meat Science, 42: 37–48.

Han S.K., Kim S.M., Pyo B.S. (2003): Antioxidative effect of glasswort (*Salicornia herbacea* L.) on the lipid oxida-

doi: 10.17221/152/2016-CJFS

tion of pork. Korean Journal of Food Science and Animal Resource, 23: 46–49.

Jimenez-Colmenero F., Ventanas J., Toldrá F. (2010): Nutritional composition of dry cured ham and its role in a healthy diet. Meat Science, 84: 585–593.

Jo Y.C., Ahn J.H., Chon S.M., Lee K.S., Bae T.J., Kang D.S. (2002): Studies on pharmacological effects of glasswort (*Salicornia herbacea* L.). Korean Journal of Medicinal Crop Science, 10: 93–99.

Kim H.W., Hwang K.E., Song D.H., Kim Y.J., Ham Y.K., Yeo I.J., Jeong T.J., Kim C.J. (2014a): Effects of red and green glassworts (*Salicornia herbacea* L.) on physicochemical and textural properties of reduced-salt cooked sausages. Korean Journal of Food Science and Animal Resource, 34: 378–386.

Kim H.W., Hwang K.E., Song D.H., Kim I.J., Lim Y.B., Ham Y.K., Yeo E.J., Chang S.J., Choi Y.S., Kim C.J. (2014b): Effect of glasswort (*Salicornia herbacea* L.) on the texture of frankfurters. Meat Science, 97: 513–517.

Kim S.M. (2013): Quality characteristics of low-salt kimchi with salt replaced by *Salicornia herbacea* L. powder. Korean Journal of Dietary Culture, 28: 674–683.

Kremer S., Mojet J., Shimojo R. (2009): Salt reduction in foods using naturally brewed soy sauce. Journal of Food Science, 74: 255–262.

Lim D.G., Choi K.S., Kim J.J., Nam K.C. (2013): Effects of *Salicornia herbacea* powder on quality traits of sun-dried hanwoo beef jerky during storage. Korean Journal of Food Science and Animal Resource, 33: 205–213.

Man C.M. (2007): Technological functions of salt in food products. In: Kilcast D., Angus F. (eds): Reducing Salt in Foods: Practical Strategies. Philadelphia, Woodhead Publishing: 157–173.

Marusic N., Petrovic M., Vidacek S., Petrak T., Medic H. (2011): Characterization of traditional Istrian dry-cured ham by means of physical and chemical analyses and volatile compounds. Meat Science, 88: 786–790.

Matthews K., Strong M. (2005): Salt-its role in meat products and the industry's action plan to reduce it. Nutrition Bulletin, 30: 55–61.

Mcgough M.M., Sato T., Rankin S.A., Sindelar J.J. (2012): Reducing sodium levels in frankfurters using naturally brewed soy sauce. Meat Science, 9: 169–178.

Meilgaard M., Civille G., Carr B. (1991): Sensory Evaluation Techniques. 2nd Ed. Boca Raton, CRC Press.

Merz B., Alberts M.J., Balady G.J., Ballantyne C.M., Berra K., Black H.R., Blumenthal R.S. , Davidson M.H., Fazio S.B., Ferdinand K.C., Fine L.J., Fonseca V., Franklin B.A., McBride P.E., Mensah G.A., Merli G.J., O'Gara P.T., Thompson P.D., Underberg J.A. (2009): ACCF/AHA/ACP Competence and training statement: a curriculum on prevention of cardiovascular disease. Journal of the American Colleague of Cardiology, 54: 1336–1363.

MFDS (1996): The Korea standards for meats retail cuts trading. Chungcheongbuk-do, Korea, Ministry of Food and Drugs Safety.

MFDS (2014): General Analysis Methods of the Ministry of Food and Drug Safety of Korea. 9th Ed. Chungcheongbuk-do, Korea.

Papadima S.N., Bloukas J.G. (1999): Effect of fat level and storage conditions on quality characteristics of traditional Greek sausages. Meat Science, 51: 103–113.

Resano H., Sanjuan A.I., Albisu L.M. (2007): Consumers' acceptability of cured ham in Spain and the influence of information. Food Quality and Preference, 18: 1064–1076.

Rhee M.H., Park H.J., Cho J.Y. (2009): *Salicornia herbacea*: Botanical, chemical, and pharmacological review of halophyte marsh plant. Journal of Medical Plants Research, 3: 548–555.

Seong P.N., Park K.M., Kang S.M., Kang G.H., Cho H.S., Park B.Y., Ba H.V. (2014): Effect of particular breed on the chemical composition, texture, color, and sensorial characteristics of dry-cured ham. Asian Australian Journal of Animal Science, 27: 1164–1173.

Seong P.N., Park K.M., Kang S.M., Kang G.H., Cho H.S., Park B.Y., Ba H.V. (2015): The impact of addition of shiitake on quality characteristics of frankfurter during refrigerated storage. LWT-Food Science and Technology, 62: 62–68.

Stamler J., Caggiula A., Grandits G.A., Kjelsberg M., Cutler J.A. (1996): Relationship to blood pressure of combinations of dietary macronutrients. Findings of the multiple risk factor intervention trial (MRFIT). Circulation, 94: 2417–2423.

Strazzullo P., Delia L., Kandala N.B., Cappuccio F.P. (2009): Salt intake, and cardiovascular disease: Meta analysis of prospective studies. British Medicine Journal, 24: 339.

Tanasescu M., Cho E., Manson J.E., Hu F.B. (2004): Dietary fat and cholesterol and the risk of cardiovascular disease among women with type 2. Diabetes, 79: 999–1005.

Toldrá F., Aristoy M.C. (2010): Dry-cured ham. In: Toldrá F. (ed.): Handbook of Meat Processing. Ames, Wiley-Blackwell: 351–362.

U.S. Food and Drug Administration (2012): Helping consumers reduce sodium intake. Available at http://www.fda.gov/ForConsumers/ConsumerUpdates/ucm327369.htm (accessed Nov 27, 2012).

Uguz S., Soyer, A., Dalmis U. (2011): Effects of different salt contents on some quality characteristics during processing of dry-cured Turkish pastirma. Journal of Food Quality, 34: 204–211.

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