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ARTICLE

Meat Quality and Storage Characteristics of Pork Loin Marinated in Grape Pomace

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Abstract

This study investigated the meat quality and storage characteristics of pork loin marinated in grape pomace powder during different storage periods. The experimental design included six treatments : pork loin containing only 100% water (Control, C); pork loin containing a combination of 20% grape pomace and 80% water (T1); pork loin containing a combination of 40% grape pomace and 60% water (T2); pork loin containing a combination of 0.5% grape pomace powder and 95.5% water (T3); pork loin containing a combination of 1.0% grape pomace powder and 99.0% water (T4); and pork loin containing a combination of 2.0% grape pomace powder and 98.0% water (T5). The pork loins aged by grape pomace and grape pomace powder showed decreased crude protein, crude fat, crude ash, pH, redness, and yellowness values; however, their moisture, lightness, and shear force increased significantly. During cold storage, marination with grape pomace and grape pomace powder reduced the 2-thiobarbituric acid value, volatile basic nitrogen value, and total microbial count in pork loin. Thus, marination with grape pomace and grape pomace powder improved the meat quality and storage characteristics, and could be used to improve storage stability of pork loin.

Keywords pork loin, grape pomace, polyphenol, quality characteristics, storage characteristics

Introduction

The consumption patterns of pork show that Koreans prefer *samgyupsal* (Korean-style bacon), pork neck, and rib, which account for about 31.8% of meat consumed, and relatively fewer consumers prefer fore limbs, hind legs, and bowels, which account for 21.5%, and by-products, such as pork bones, and viscera, which occupy 46.7%. Hair, ankles, non-favored sites, and by-products account for 68.2% of the whole porcine carcass of slaughtered livestock (Annual Handbook of Meat By-Products, 2010). Consumption of *samgyupsal* and pork neck, which are preferred by consumers, has steadily increased, and the volume imported has continued to increase because of domestic production shortages. However, because the consumption of the fore limbs, hind legs, pork loin, and other parts that consumers do not like is low, an imbalance in pork consumption occurs. The non-preferred por-

tions of pork are consumed as sausages, hams, jerky, and balls; however, it is difficult to manage a processing company because the purchasing power of meat products is lower than that of roasting pork since purchasing the meat products is lower than the roasting pork, it is increasingly difficult to inventory management of the meat processing company (Korea Meat Trade Association, 2015). There have been many studies to promote the consumption of the non-favored parts, and efforts have been made to improve quality by developing meat products with natural functional materials (Kim *et al*., 2015; Park, 2014; Park and Chin, 2007).

Grapes are one of the representative fruits of the world, and among the fruit preferences of Korean consumers, 42.7% prefer grapes (Agricultural Products Consumption Actual Condition, 2006). The increase in grape consumption was not only caused by a preference for grapes but also because of the phytochemicals in the grapes, which are known to have beneficial physiological activities. Red wine, produced by ripening whole grapes, contains a large amount of polyphenol compounds (Garcia-Marino *et al.,* 2010), which been reported to prevent arteriosclerosis (Waddington *et al.,* 2004), and cancer (Soleas *et al.*, 1997), and have an antioxidant effect (Passamonti *et al.,* 2005). In addition, red wine contains quercetin, myricetin, catechin, and epicatechin, which match well with many meat products that contain a lot of fat (Aruoma, 1996). In particular, the high antioxidant activity of grape products is one explanation for the significantly lower incidence of heart disease in French people who consume large amount of meat compared with that in Americans (Ulbright and Southgate, 1991). It has been reported that the addition of red wine improves the quality of meat products (Youn *et al.*, 2007a; Youn *et al.*, 2007b).

There is growing interest in the recycling of grape residue wastes produced during wine processing. Grape clusters contain peel, seeds, and pulp. Grape seeds account for about 3% of the fresh weight, and about 15% of grape skin occurs as waste, producing a maximum of about 4.5 tons per year in Korea (Chang *et al.,* 2010). Phenolic compounds extracted from grape leaves prevent blood clotting (Olas and Wachowicz, 2005) and inhibit the production of reactive oxygen species (ROS) (Leonard *et al.,* 2003; Marhinez and Moreno, 2000; Vitseva *et al.,* 2005).

The present study was carried out to investigate the effect of grape pomace addition and aging time on the meat quality and storage characteristics during the ripening of pork loin.

Materials and Methods

Sample preparation

The pork loin used in this experiment was supplied by Nature & Farmer Co., Ltd in Goesan-gun, Chungbuk province in Korea. The grape pomace was purchased from Dorian Won, a wine maker in Yeongdong-gun, Chungbuk Province in Korea, and came from the Campbell Early (*Vitis labruscana* Bailey) variety. The skins and seeds of the grape pomace are easily crushed; therefore, the liquid grape pomace is mixed with 1 L of distilled water and ground in a mixer (HMF-3160S, Hanil, Korea). The grape pomace powder was prepared by freezing the liquid grape pomace at -70°C, drying it in a freeze drier (ED 8512, Ilshin, Korea), grinding it using a grinder (HR2904, Philips Co., Netherlands). The experimental groups comprised the Control group (pork loin containing only 100% distilled water), T1 (pork loin containing a combination of 20% grape pomace and 80% distilled water), T2 (pork loin containing a combination of 40% grape pomace and 60% distilled water), T3 (pork loin containing a combination of 0.5% grape pomace powder and 95.5% distilled water), T4 (pork loin containing a combination of 1.0% grape pomace powder and 99.0% distilled water), and T5 (pork loin containing a combination of 2.0% grape pomace powder and 98.0% distilled water). The grape pomace mixture was prepared for aging the pork. For aging, 100 g of raw meat was immersed in 1 L of grape pomace mixture for 72 h at 4°C. To investigate the quality change of pork loin over time, pH, shear force, and meat color were measured at 3, 24, and 48 h. After 72 h of ripening, the ripened meat was vacuum-packed and stored at 4°C for 10 d. At 0, 5, and 10 d, general components, pH, 2-thiobarbituric acid, volatile basic nitrogen, and total aerobic bacteria were measured. The analysis of each sample was repeated three times.

Proximate composition

Moisture, protein, fat, and ash (%) were determined according to the method of the AOAC (1990). Moisture was analyzed by heat drying at 105°C, the micro-Kjeldahl method was used for crude protein determination, soxhlet extraction was used for crude fat determination, and filtration was used to determine the content. Calorimetric analysis was performed using a calorimeter (PARR 1351 Bomb Calorimeter, USA).

Assay of the total polyphenol content of grape pomace

The analysis of the total polyphenol content was carried out according to the slightly modified method of Folin and Denis (1912). One mL of grape pomace ethanol extract and 2 mL of Folin reagent were put into a test tube, and allowed to stand for 3 min at room temperature. Subsequently, 2 mL of 10% Na_2CO_3 was added into the tube. The solution in the tube was mixed thoroughly and allowed to stand for 40 min at 30°C, and then the absorbance of the solution was measured at 760 nm, using a UV-spectrophotometer (Shimadzu UV-1601PC, Japan). A standard curve was plotted from the prepared samples so that the final concentration of the samples became 0, 0.2, 0.4, 0.6, 0.8, and 1.0 mg/mL using tannic acid, and the total polyphenol content of the sample was obtained from this calibration curve.

High-performance liquid chromatography (HPLC) analysis of polyphenol

HPLC analysis was performed according to the method described by Šruga *et al.* (2011) and catechin, ρ-coumaric acid, ferulic acid, hesperidin, hesperetin, naringenin, and cinnamic acid levels among the polyphenols were analyzed. For HPLC analysis, a Nova-Pak C18 column (4 μm, 150 × 3.9 mm id, Waters, USA) was used. Solvent A, as a moving phase, was water:acetic acid (95:5, v/v), and solvent B was methanol:acetonitrile (50:50, v/v). Starting with a Solvent A:B ratio of 95:5 (v/v), the samples were analyzed using solvents with A:B ratios of 70:30 (v/v) after 25 min and 65:35 (v/v) after 10 min, 60:40 (v/v) after 5 min, 30:70 (v/v) after 1 min, and finally 0:100 (v/v) after 10 min. The flow rate was 1.0 mL/min and the injection volume was 10 μL. The flow rates were obtained after analysis in a UV 830 detector at 278 nm. Ten milligrams of gallic acid, (+)-catechin, ρ-coumaric acid, ferulic acid, hesperidin, hesperetin, naringenin and cinnamic acid were dissolved in 1 mL of methanol for HPLC, individually, and used as a stock solution. The stock solutions were serially diluted and used as calibration standard solutions. Then, 10 μL of each standard solution was analyzed by HPLC, the chromatogram area of each peak was obtained, and a calibration curve according to concentration and area was prepared to calculate the content in the experimental samples. To prepare the sample, 10 mg of each fraction extract was dissolved in 1 mL of methanol and filtered through a syringe filter (0.5 μm PTFE, Adventec, Japan). The filtrate was used as a sample and analyzed twice.

Determination of the pH

The pH values of the pork loins were determined according to the method of Khalil (2000). Ten grams of sample added with 100 mL of distilled water were homogenized for 30 s using a blender (400 Lab Blender, Seward, UK). The pH of sample was measured using a pH-meter (pH 720, WTW Laboratory Instrument, Germany).

Shear force test

Shear force measurements were performed according to method of Wheeler *et al.* (2000). The muscle was sheared so as to be perpendicular to the direction of the muscle fiber in the shape of a 3 cm-thick stake, heated to 70°C, and allowed to cool for 30 min in running water. A 1 cm diameter core of the cooled sample was drilled in a cylindrical shape in the direction of the muscle fiber, and the maximum weight was measured using a shearing and cutting test using a Rheometer (Compac-100, Sun Scientific Co., Japan). The program used was RDS (Rheology Data System) Ver. 2.01. The table speed was 110 mm/min, the graph interval was 20 m/s, and the load cell (Max) was 10 kg.

Instrumental color evaluation

The meat color was measured using a spectrocolorimeter (Model JX-777, Color Techno System Co., Japan) that was standardized to the white plate (lightness (L), 94.04; redness (a), 0.13; and yelllowness (b), -0.51). At this time, a white fluorescent lamp (D65) was used as the light source, and the meat color was indicated with L value that representing the lightness of the Hunter lab color coordinates, a value representing the redness, and b value representing the yellowness.

2-thiobarbituric acid (TBA) value

The 2-thiobarbituric acid (TBA) value was measured by the modified extraction method of Witte *et al.* (1970). Ten grams of each sample were taken, and 15 mL of cold 10% perchloric acid and 25 mL of triple distilled water were added to sample. After homogenizing the sample at 10,000 rpm for 10 s in a homogenizer (AM-Series), the homogenate was filtered using qualitative filter paper No. 2. The filtrate solution (5 mL) was mixed with 5 mL 0.02 M TBA solution, and its absorbance was measured at 529 nm using a spectrophotometer (DU-650, Beckman, USA) after allowing to stand it for 16 h in a cool and dark place. Triple distilled water was used in the blank. TBA value was expressed as mg of malonaldehyde per 1 kg sample (mg malonaldehyde kg). The TBA level was calculated using a

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standard curve, where y=0.1975x−0.0011 (r=0.999), and expressed by calculating y = absorbance and x = the TBA value.

Volatile basic nitrogen (VBN) value

The content of volatile basic nitrogen (VBN) was measured by microdiffusion analysis (Short, 1954) using a Conway unit. Ten grams of each sample were added to 90 mL of distilled water and homogenized at 10,000 rpm for 30 s in a homogenizer (AM-Series). The homogenate was filtered using qualitative filter paper No. 2. One milliliter of the filtrate was put in the outer chamber of the Conway unit, and 1 mL of 0.01 N boric acid and three drops of indicator (0.066% methyl red + 0.066% bromocresol green) were added into the inner chamber. Glycerine was then applied to glue the parts to the lid, and the lid was closed. One milliliter of 50% K_2CO_3 was then injected into the outer chamber. Thereafter, the Conway unit was sealed immediately. After horizontally stirring the vessel, the boric acid in the inner chamber was titrated with 0.02 N H_2SO_4 after incubating at 37°C for 120 min. The value of VBN was expressed by converting it to mg (mg%) per 100 g sample.

$$VBN = \{(a - b) \times F \times 28.014 \times 100\} / \text{amount of sample}$$

a: Amount of injected sulfuric acid (mL)
b: Amount of sulfuric acid injected in blank (mL)
F: Standardized index of 0.02 N H_2SO_4
28.014: Amount of required to consume 0.02 N H_2SO_4 of 1 mL

Total Microbial Count (TMC)

Ten gram samples of pork loin were taken aseptically from each treatment, transferred to sterile plastic pouches, and homogenized with 90 mL 0.1% peptone solution in a blender (400 Lab Blender, Seward, UK) for 1.5 min. Serial 10-fold dilutions were prepared from each sample using 1 mL in fluid agar, which were then inoculated on plate count agar (PCA) medium and incubated for 48 h at 37°C (APHA, 1992). The results were expressed as the log of colony forming unit (CFU)/g.

Statistical analysis

The data were tested using analysis of variance in the SAS program (SAS, 2012) and statistical significance was verified at the 5% level using Duncan's multiple range test.

Results and Discussion

Phenolic compound contents

The contents of gallic acid, (+)-catechin, ρ-coumaric acid, ferulic acid, hesperidin, hesperetin, naringenin, and cinnamic acid were significantly higher in the peel and grape seed preparation than in the grape peel alone samples (Table 1). For grapes, phenol compounds are present at less than 10% in flesh, 60-70% in seeds, and 28-35% in skins (Shi *et al.,* 2003). Lazze *et al.* (2009) also reported that wine by-product extracts contain malvidin, catechin, epicatechin, and gallic acid at 34.86, 69.53, 50.90, and 18.64 mg/kg, respectively. Tournour *et al.* (2015) reported that the total polyphenol content of wine by-product in Portugal was 69.30 mg/g, and the main phenol compounds were syrignic acid and (+)-catechin. The total polyphenol content of grape pomace used in this study was high. Fresh meat and processed meat deteriorate in various ways, such as texture, taste, and nutritional content of products because of fat oxidation occurring during storage. Therefore, the high levels of various polyphenols in grape pomace suggested that it would be a natural antioxidant that could inhibit lipid oxidation of meat products.

Proximate composition of pork loin marinated in grape pomace

The proximate composition of the pork loin samples marinated in grape pomace is shown in Table 2. The moisture content of the marinated pork loin was 72.77-76.07%, the protein content was 20.27-21.82%, the fat content was

Table 1. Phenolic compound contents of grape skin and seed extracts from grape pomace

Samples	Phenolic compound contents (μg/g d.b)[1)]								
	GA	C	PCA	FA	H	HT	N	CA	Total
Grape skin	4.71±0.82[2)]	73.31±3.75	0.98±0.25	1.87±0.10	15.89±2.92	1.39±0.17	9.14±0.60	ND	107.29±7.92
Grape skin+ Grape seed	9.00±1.03	160.40±4.76	2.11±0.20	4.06±0.34	17.87±0.97	3.15±0.21	10.66±0.37	0.69±0.10	207.94±8.01

[1)]GA, gallic acid; C, (+)-catechin; PCA, ρ-coumaric acid; FA, ferulic acid; H, hesperidin; HT, hesperetin; N, naringenin; CA, cinnamic acid; Total, total contents; ND, not detected
[2)]All values are expressed as means±SD (n=3).

Table 2. Approximate compositions of marinated pork loin prepared by adding grape pomace

Treatments[1)]	(%)			
	Moisture	Protein	Fat	Ash
CON	72.77±0.64[c]	22.22±0.80[a]	3.90±0.43[a]	1.09±0.06[a]
T1	74.27±0.18[b]	21.19±0.12[abc]	3.77±0.06[ab]	0.75±0.02[bc]
T2	73.66±0.27[b]	21.82±1.10[ab]	3.71±0.90[abc]	0.80±0.03[b]
T3	75.63±0.63[a]	20.74±0.38[bc]	3.00±0.20[bc]	0.61±0.06[d]
T4	76.07±0.28[a]	20.27±0.34[bc]	2.93±0.08[c]	0.72±0.06[bc]
T5	75.56±0.26[a]	20.86±0.29[c]	2.90±0.15[c]	0.66±0.05[cd]

[1)]CON, Control (No addition); T1, 20% grape pomace + 80% distilled water; T2, 40% grape pomace + 60% distilled water; T3, 0.5% grape pomace powder + 99.5% distilled water; T4, 1.0% grape pomace powder + 99.0% distilled water; T5, 2.0% grape pomace powder + 98.0% distilled water

[a-d]Means±SD with different superscripts in the same column differ significantly (p<0.05).

2.90-3.90%, and the ash content was 0.61-1.09%. The moisture content of pork loin samples marinated in grape pomace powder was significantly higher than that of the other treatments and the protein content of pork loin samples marinated in grape pomace powder was significantly lower than that of the other treatments, with T4 having the lowest value at 20.27%. The fat content of pork loin samples marinated in grape pomace powder was significantly lower than that of other treatments, with T5 showing the lowest value at 2.90%. The ash content was the highest in Control group, and the pork loin samples marinated in grape pomace powder showed significantly lower ash contents than the other treatments, with T3 showing the lowest value at 0.61%. Therefore, treatment with grape pomace and grape pomace powder during pork loin ripening seemed to affect its general composition. Yoo *et al.* (2008) reported that moisture content in muscles is increased by denaturation of protein in meat by organic acids of grape pomace.

pH and shear force of the pork loin marinated in grape pomace

Table 3 shows the changes in pH and shear force of pork loin marinated with grape pomace and grape pomace powder during aging at 4°C. The pH of grape pomace-marinated pork loin tended to decrease as the grape pomace and grape pomace powder contents increased. After 24 h of aging, the pH was 4.97 in T2 group, which was significantly lower than that in the other treatments. The pH tended to decrease in all treatments until 24 h of ripening, but increased at 48 h of ripening, except in the Control and T4 groups. The pH of grape pomace and grape pomace powder were 3.56 and 3.64, respectively (data not shown); thus, treatment with grape pomace and grape pomace powder affected the pH of pork loin. Most of the organic acids contained in grapes are tartaric acid and citric acid, and Mato *et al.* (2005) reported that as grapes ripen, succinic acid, lactic acid, galacturonic acid, glucuronic acid, citramalic acid, pyruvic acid, and ketoglutaric acid are produced. Thus, we hypothesized that the pH of pork loin decreased because of the presence of these various organic acids in the grape pomace and grape pomace powder. Jung *et al.* (2007) also showed that the pork patties treated with wine had a lower pH than the non-treated patties.

For the shear force, the Control group showed significantly lower value at 3 h of ripening; however, this seems

Table 3. pH and shear force during ripening of grape pomace marinated pork loin

Items	Aging time (h)	Treatments[1)]					
		CON	T1	T2	T3	T4	T5
pH	3	5.86±0.00[a]	5.60±0.02[c]	5.56±0.02[d]	5.59±0.00[cd]	5.65±0.01[b]	5.59±0.02[cd]
	24	5.83±0.00[a]	5.18±0.01[e]	4.97±0.01[f]	5.49±0.01[b]	5.37±0.00[c]	5.30±0.01[d]
	48	5.75±0.01[a]	5.19±0.01[e]	5.17±0.03[e]	5.57±0.01[b]	5.48±0.02c	5.30±0.01[d]
Shear force (kg)	3	1.46±0.16[b]	1.67±0.23[ab]	1.58±0.12[ab]	1.99±0.47[a]	1.74±0.44[ab]	1.96±0.08[a]
	24	1.47±0.13[bc]	1.63±0.20[ab]	1.43±0.09[b]	1.84±0.09[a]	1.56±0.35[b]	1.88±0.15[a]
	48	1.47±0.22[b]	1.75±0.20[a]	1.50±0.18[b]	1.63±0.07[ab]	1.51±0.08[b]	1.74±0.12[a]

[1)]CON, Control (No addition); T1, 20% grape pomace + 80% distilled water; T2: 40% grape pomace + 60% distilled water; T3, 0.5% grape pomace powder + 99.5% distilled water; T4, 1.0% grape pomace powder + 99.0% distilled water; T5, 2.0% grape pomace powder + 98.0% distilled water

[a-f]Means±SD with different superscripts in the same row differ significantly (p<0.05).

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to be caused by site deviation. At 24 h of ripening, except for the Control group, all treatments showed significantly lower shear force values than at 3 h of ripening. The shear force of the grape pomace and grape pomace powder-treated groups (T1, T2, T3, T4, and T5) was significantly higher than that of the Control group at 48 h. The shear force of meat products has been reported to vary with the pH, amount of fat, amount and texture of connective tissue, effect of actomyosin, and length of the cut muscle (Lorenzen *et al.,* 1999). Hah (2005) reported that when the pH of the meat is reduced and the pH of the meat becomes closer to the isoelectric point, the moisture of the meat exudes and the shear force increases.

Meat color changes during ripening of marinated pork loin

Table 4 shows the measurements of color change during ripening of pork loin marinated with grape pomace. The L* (lightness) of the color of grape pomace-marinated pork loin was significantly higher in all treatments compared with that of the Control group, and the pork loin marinated with grape pomace powder (T3, T4, and T5) showed significantly higher lightness than those in the grape pomace-treated group (T1 and T2) (p<0.05). The L* value of 40% grape pomace-treated group (T2) was lower than that of 20% grape pomace-treated group (T1). However, there was no consistent trend in the color change of grape pomace powder-treated groups (T3, T4, and T5) depending on the level of pomace addition. The a* value, indicating redness, was slightly higher in the Control group compared with that in the treatment groups (T1, T2, T3, T4, and T5) at 3 h of ripening. However, at 24, and 48 h of ripening, the value of the group treated with 40% grape pomace (T2) was significantly higher than that of the other treatments (p<0.05). The b* value (yellowness) was significantly higher in the Control and 20% grape pomace treated group (T1) than the in the other treatments at 3 h of ripening, and the groups treated with grape pomace powder (T3, T4, and T5) showed significantly lower b* values than those treated with grape pomace (T1 and T2) (p<0.05). At 24 h of ripening, the 0.5% grape pomace powder-treated group (T3) and the 1.0% grape pomace powder-treated group (T4) had significantly lower b* values than the other treatments, and the grape pomace powder treatments showed lower b* values than grape pomace treatments at 48 h.

Park *et al.* (2011) showed that the L* and b* values increased with increasing the amounts of red wine. It was proposed that the anthocyanin content of red wine (Garcia-Marino *et al.,* 2010) might have affected those values, and the reason for the high b* value was reported to be the effect of pyranoanthocyanin (He *et al.,* 2006), which is a yellowish red pigment produced during the ripening of red wine. By contrast, in the case of pork sausages treated with grape pomace, it was reported that as the amount of grape pomace increased, the L* and a* values decreased, and the b* value increased (Ryu *et al.,* 2014); it was suggested that this tendency was attributed to the effects of polyphenols and carotenoids in the grape pomace.

Changes in pH, TBA, VBN, and TMC during storage of marinated pork loin

The changes in pH, TBA, VBN, and TMC during 10 d of storage of grape pomace and grape pomace powder-marinated pork loin are shown in Table 5. The pH of the grape pomace-marinated pork loin during storage was sig-

Table 4. Color change of grape pomace-marinated pork loin during ripening

Items	Aging time (h)	Treatments[1)]					
		CON	T1	T2	T3	T4	T5
[2)]CIE L*	3	54.99±1.78^{d}	66.99±1.98^{b}	62.85±2.69^{c}	67.60±3.73^{b}	74.61±2.49^{a}	72.14±0.58^{a}
	24	52.98±1.67^{d}	68.34±1.02^{c}	67.68±0.76^{c}	77.04±1.74^{a}	72.65±1.66^{b}	75.59±1.52^{a}
	48	55.33±2.27^{d}	71.87±1.26^{b}	67.43±1.16^{c}	78.92±1.91^{a}	77.79±0.99^{a}	73.85±1.75^{b}
CIE a*	3	8.68±0.69^{a}	6.85±0.46^{b}	7.59±0.54^{ab}	6.49±1.44^{b}	7.45±0.99^{ab}	6.53±0.90^{b}
	24	6.92±0.47^{c}	7.29±0.41^{c}	9.30±0.68^{a}	5.61±0.44^{d}	4.90±0.72^{d}	8.47±0.88^{b}
	48	7.57±0.69^{b}	7.39±0.83^{b}	9.61±0.65^{a}	6.40±0.82^{c}	6.21±0.51^{c}	7.05±0.59^{bc}
CIE b*	3	8.97±0.58^{a}	7.62±0.17^{a}	7.78±0.60^{b}	6.19±0.88^{c}	6.08±0.43^{c}	6.75±0.56^{c}
	24	9.02±0.58^{a}	8.58±0.58^{a}	8.41±0.79^{a}	6.15±0.34^{b}	6.51±0.60^{b}	8.32±0.87^{a}
	48	9.04±0.47^{b}	9.05±0.41^{b}	10.15±0.36^{a}	7.19±0.92^{c}	8.35±0.94^{b}	8.71±0.48^{b}

[1)]CON, Control (No addition); T1, 20% grape pomace + 80% distilled water; T2, 40% grape pomace + 60% distilled water; T3, 0.5% grape pomace powder + 99.5% distilled water; T4, 1.0% grape pomace powder + 99.0% distilled water; T5, 2.0% grape pomace powder + 98.0% distilled water.
[2)]L*, lightness; a*, redness; b*, yellowness
[a-d]Means±SD with different superscripts in the same row differ significantly (p<0.05).

Table 5. Changes in pH, 2-thiobarbituric acid (TBA), volatile basic nitrogen (VBN), and total microbial count (TMC) during storage of grape pomace-marinated pork loin

Items	Storage day	Treatments[1)]					
		CON	T1	T2	T3	T4	T5
pH	0	5.86±0.02^{a}	5.53±0.02^{c}	5.50±0.05^{c}	5.66±0.02^{b}	5.66±0.01^{b}	5.53±0.03^{c}
	5	5.81±0.01^{a}	5.61±0.01^{b}	5.49±0.03^{c}	5.58±0.01^{b}	5.50±0.00^{c}	5.44±0.01^{d}
	10	5.68±0.00^{a}	5.28±0.01^{d}	5.29±0.01^{d}	5.48±0.01^{b}	5.37±0.00^{c}	5.47±0.02^{b}
TBA (mg MA/kg)	0	0.20±0.01^{b}	0.21±0.00^{b}	0.25±0.00^{a}	0.10±0.00^{d}	0.12±0.00^{c}	0.11±0.00^{cd}
	5	0.24±0.00^{b}	0.16±0.00^{cd}	0.28±0.00^{a}	0.14±0.00^{d}	0.18±0.04^{cd}	0.19±0.03^{c}
	10	0.19±0.01^{b}	0.23±0.02^{a}	0.27±0.04^{a}	0.14±0.02^{c}	0.17±0.00^{bc}	0.16±0.02^{bc}
VBN (mg%)	0	17.57±0.72^{a}	15.37±0.27^{b}	15.09±0.38^{b}	13.72±0.82^{cd}	13.54±0.57^{d}	14.82±0.72^{bc}
	5	19.58±0.41^{a}	14.64±0.15^{cd}	15.83±0.27^{b}	14.04±0.19^{d}	14.55±0.41^{cd}	15.37±1.14^{bc}
	10	23.88±0.95^{a}	18.11±1.94^{c}	18.39±0.27^{c}	20.72±2.91^{bc}	22.42±0.57^{ab}	19.85±1.14^{bc}
TMC (Log CFU/g)	0	3.65±0.10^{b}	3.54±0.05^{b}	3.48±0.01^{b}	4.03±0.17^{a}	3.49±0.13^{b}	3.62±0.04^{b}
	5	4.47±0.02^{a}	4.08±0.06^{c}	3.73±0.09^{d}	4.32±0.00^{b}	4.01±0.04^{c}	3.79±0.05^{d}
	10	5.13±0.00^{a}	3.34±0.02^{c}	2.99±0.21^{d}	4.77±0.01^{b}	4.63±0.03^{b}	3.30±0.03^{c}

[1)]CON, Control (No addition); T1, 20% grape pomace + 80% distilled water; T2, 40% grape pomace + 60% distilled water; T3, 0.5% grape pomace powder + 99.5% distilled water; T4, 1.0% grape pomace powder + 99.0% distilled water; T5, 2.0% grape pomace powder + 98.0% distilled water
[a-d]Means±SD with different superscripts in the same row differ significantly (p<0.05).

nificantly higher than that of grape pomace-treated group for the total storage period (p<0.05) and the pH tended to decrease with increasing storage period in all pork loin groups. At 0, and 10 d of storage, grape pomace treatments tended to have lower pH than grape pomace powder treatments. The grape pomace powder treatments (T3, T4, and T5) had significantly lower TBA values than that of the Control and grape pomace treated groups (T1 and T2), on all storage test days (p<0.05). On the other hand, treatment with 40% grape pomace (T2) resulted in the highest TBA values compared to the other treatments during the storage period. The VBN contents of the treated groups (T1, T2, T3, T4, and T5) were lower than those of the Control group during storage for 10 d. The pork loins treated with grape pomace powder showed lower VBN contents than those treated with grape pomace treatments at 0 d of storage, but grape pomace powder treatments showed higher values at 10 d of storage compared with the grape pomace-treated groups. The TMC was significantly higher in the 0.5% grape pomace powder-treated group (T3) than that in the Control group at 0 d of storage, but was not significantly different in the other treatments. On the 5th and 10th d of storage, the Control group showed significantly higher TMC values compared with those in the treatment groups. As the level of grape pomace and grape pomace powder increased, total the TMC decreased. Similarly, Youn *et al.* (2007a) reported that the addition of red wine to pork patties suppressed the growth of bacteria and lowered the levels of 2-thiobarbituric acid reactive substances (TBARS). Jung *et al.* (2008) reported that the addition of red wine to beef jerky reduced the VBN and total bacteria contents.

The phenolic hydroxyl (OH) group present in the phenolic compounds can bind with proteins and has physiological activities, such as antioxidant, anticancer and antibacterial effects (Droge, 2001; Hogan *et al.,* 2010). Vuorela *et al.* (2005) reported that the addition of phenolic compounds inhibited lipid oxidation. The results of this study also suggested that treatment with grape pomace and grape pomace powder decreased lipid peroxidation, the VBN content, and the microbial count in marinated pork loin, probably because of the abundance of polyphenol content in the grape products. Organic acids present in nature inhibit the growth of microorganisms (Blocher and Busta, 1983). Therefore, it is speculated that the various organic acids produced during the ripening process of wine inhibited the growth of microorganisms, reduced the activity of enzymes, and inhibited the production of basic substances.

Conclusions

The total polyphenol content of grape pomace used in this study was 207.943±8.01 (μg/g d.b) and the content of gallic acid, (+)-catechin, ρ-coumaric acid, ferulic acid, hesperidin, hesperetin, naringenin and cinnamic acid was high. These results suggested that marination of ripening of pork loin with grape pomace or grape pomace powder decreases the pH and color, increases the shear force, and inhibits the increase of lipid peroxidation, volatile basic nitrogen, and the growth of microorganisms. Thus, we con-

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cluded that treatment with grape pomace or grape pomace powder might improve the preservation of pork loin.

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