Korean J. Food Sci. An. Vol. 36, No. 3, pp. 369~376(2016)
© 2016 Korean Society for Food Science of Animal Resources
DOI http://dx.doi.org/10.5851/kosfa.2016.36.3.369
ISSN 1225-8563 eISSN 2234-246X

ARTICLE

Quality Improvement of Pork Loin by Dry Aging

Cheol Woo Lee, Ju Ri Lee, Min Kyu Kim, Cheorun Jo[1], Kyung Haeng Lee[2], Insin You[3], and Samooel Jung*

Division of Animal and Dairy Science, Chungnam National University, Daejeon 34134, Korea
[1]Department of Agricultural Biotechnology, Center for Food and Bioconvergence, and Research Institute of Agricultural and Life Science, Seoul National University, Seoul 08826, Korea
[2]Department of Food and Nutrition, Korea National University of Transportaion, Jeungpyung 27909, Korea
[3]SD Food Company, Buyeo 33117, Korea

Abstract

This study aimed to investigate the effects of dry aging on the quality of pork loin. *Longissimus lumborum* muscles were dissected from the right half of five pork carcasses and were used as the control samples. The left halves of the carcasses were aged at 2±1°C and a relative humidity of 80% for 40 d. The total aerobic bacteria count was similar between the control and dry-aged pork loin (p>0.05). Lactic-acid bacteria was absent in both the control and dry-aged pork loins. Dry-aged pork loin contained low moisture and high protein and ash compared to the controls (p<0.05). The pH was higher and cooking loss was lower in dry-aged pork loin compared to that in the control (p<0.05). Flavor related compounds, such as total free amino acid, hypoxanthine, and inosine of pork loin were higher in dry-aged pork loin; whereas, inosine 5'-monophosphate and guanosine 5'-monophosphate were low in dry-aged pork loin than control (p<0.05). There was no difference in carnosine and anserine content between dry-aged pork loin and the control (p>0.05). Dry-aged pork loin had lower hardness and shear force and received higher core in sensory evaluation than the control (p<0.05). According to the results, dry aging improved textural and sensorial quality of pork loin.

Keywords: dry aging, pork loin, tenderness, sensorial quality

Received December 21, 2015; Revised February 25, 2016; Accepted March 28, 2016

Introduction

Pork is the most widely consumed meat in Korea (Korea Meat Trade Association, 2014). Nevertheless, the consumption of pork is concentrated in specific cuts of pork such as belly and neck. The imbalanced consumption among pork cuts may be attributed to tenderness of each cut. Tenderness is an important factor in deciding the quality of meat during consumption and its variability has an impact on the repurchase of meat by consumers (Koohmaraie, 1994; Shackelford *et al*., 2001). Various pre- and post-slaughter factors affect meat tenderness (Maltin *et al*., 2003). Intrinsic factors, such as intramuscular fat content (marbling), contribute to the tenderness of meats (Blanchard *et al*., 2000; Gruber *et al*., 2006; Smith *et al*., 2008). Therefore, various studies have reported a positive relationship between intramuscular fat content and tenderness as measured by shear force (Blanchard *et al*., 2000; DeVol *et al*., 1988; Gruber *et al*., 2006). Hence, meat containing low intramuscular fat is less tender than meat containing high intramuscular fat. Therefore, the improvement in tenderness is especially essential in the pork cuts with low intramuscular fat to alleviate the imbalanced consumption of pork cuts.

Aging is a method for improving tenderness of fresh meat by postmortem proteolysis (Maltin *et al*., 2003; Sitz *et al*., 2006). During the conversion of muscle to meat, muscles undergo rigor mortis that results in the increase in toughness of meat (Huff-Lonergan and Lonergan, 2005). However, rigor mortis can be resolved by degradation of myofibrillar and cytoskeletal proteins in meat by proteinases such as calpain, caspase, cathepsin, and proteasome while aging, which can improve the meat tenderness (Caballero *et al.*, 2007; Chen *et al*., 2015; Cruzen *et al*., 2014; Laville *et al*., 2009). Moreover, aging has an impact on the generation of desirable meat flavor as the composition and content of various flavor precursors in meat changes

*Corresponding author: Samooel Jung, Division of Animal and Dairy Science, Chungnam National University, Daejeon 34134, Korea. Tel: +82-42-821-5774, Fax: +82-42-825-9754, E-mail: samooel@cnu.ac.kr

with aging (Koutsidis *et al*., 2008).

Aging is generally categorized into wet and dry aging. Wet aging involves vacuum packaging of meat. In addition, it prevents weight loss caused by evaporation of moisture and microorganism growth. However, wet-aged meat has a bloody and metallic flavor (Campbell *et al*., 2001; Warren and Kastner, 1992). On the other hand, dry aging involves the exposure of unpacked carcasses or wholesale cuts to air at controlled temperature, relative humidity, and air-flow (Campbell *et al*., 2001). Dry aging contributes to the shrinkage and trim loss due to the dried surface. However, it has an advantage of generating unique and distinct flavors such as brown-roasted flavors (Smith *et al*., 2008). Previous studies reported that dry-aged beef has higher palatability than wet-aged beef (Ahnström *et al*., 2006; Campbell *et al*., 2001; Parrish *et al*., 1991). However, few studies have been conducted to determine the effect of dry aging on the quality of pork, especially pork cuts which contains relatively low intramuscular fat. Therefore, the objective of this study was to evaluate the influence of dry aging on the quality of pork loin (*Longissimus lumborum* muscle).

Materials and Methods

Sample preparation and dry aging

Five pork carcasses (ten half carcasses) were purchased from a large commercial processor on the day of slaughter, and transported to SD Food Co. (Korea). Pork loins (*Longissimus lumborum* muscles: 6^{th} dorsal vertebra to 6^{th} lumbar vertebra) were dissected from the right half of five pork carcasses, and used as control sample. The left half of the pork carcasses were suspended by the Achilles tendon in aging room and aged at 2±1°C and a relative humidity of 80% for 40 d. After the completion of dry aging, pork loins were dissected from the dry aged carcasses with the removal of dried surface, and used as dry aged samples. The muscle samples were individually vacuum-packaged in 50×30 cm low-density polyethylene/nylon vacuum bags, and transported to the Chungnam National University meat laboratory in insulated icebox with reusable ice packs on the day of dissection.

Each pork loin of control and dry-aged sample was divided into dorsal vertebra and lumbar vertebra parts. The dorsal vertebra parts were individually vacuum-packaged in a low-density polyethylene/nylon vacuum bags (50×30 cm) and stored at -70°C until analysis of sensory parameters. The lumbar vertebra part was cut into four sections. Three of the four sections were used as three repetition samples (observations) of each carcass. Microbial count, proximate composition, pH, cooking loss, and texture of pork loin were conducted with fresh meat (unfrozen meat) on the day of dissection. The meat samples for analysis of free amino acid content, carnosine and anserine content, and nucleotides were weiged in conical tube on the day of dissection and stored at -70°C until analysis.

Total aerobic bacteria and lactic-acid bacteria

Meat samples (10 g) were blended with sterile saline (90 mL) for 2 min by using a stomacher (BagMixer® 400; Interscience Ind., France). A series of decimal dilutions was prepared using sterile saline. Each diluent (0.1 mL) was spread on tryptic soy agar plates (Difco Laboratories, USA) for count of total aerobic bacteria and MRS agar plates (Difco Laboratories, USA) for count of lactic-acid bacteria. The plates were incubated at 37°C for 48 h, and the microbial counts were expressed as log colony-forming units/g (Log CFU/g).

Proximate composition

The moisture, crude protein, crude fat and crude ash contents of each sample were determined as outlined by AOAC (2005). Briefly, the moisture content was measured by drying the samples (2 g) at 102°C for 15 h. The crude protein content was analyzed by the Kjeldahl method (VAPO45, Gerhardt Ltd., Germany). The crude fat content was determined using the Soxhlet extraction system (TT 12/A, Gerhardt Ltd., Germany). The crude ash content was measured by igniting the sample (2 g) in a furnace at 600°C for 6 h.

pH and cooking loss

Control and dry-aged pork loins (5 g) were mixed with 45 mL of distilled water and homogenized at 1,130 *g* for 1 min using a homogenizer (T25 basic, IKA GmbH & Co. KG, Germany). The homogenate was filtered using filter paper (No. 4 filter paper, Whatman) and the filtrate was measured pH using a pH meter (SevenEasy, Mettler-Toledo, Korea).

About 30 g of pork loins were individually vacuum-packaged in a low-density polyethylene/nylon vacuum bags (20×15 cm). The packaged pork loins were cooked in a 75°C water bath for 20 min and then cooled in tab water for 10 min. Cooking loss of pork loins was examined by comparing weight of before and after cooking.

Free amino acid content

The meat sample (1.0 g) was homogenized in 10 mL of

5% TCA at 1,130 *g* for 1 min using a homogenizer (T25 basic). The homogenate was kept at 4°C for 1 h for precipitation of protein. After centrifugation at 10,000 *g* for 10 min at 4°C (HM-150IV, Hanil), the supernatant was filtered through a 0.2 μm PTFE syringe filter (Whatman, England) and the filtrate was used for the following experiments. The extraction and derivatization of amino acids were conducted by using AccQ-Tag Reagent kit (AccQ-Tag Reagent kit, Waters, USA). The 1 mL of AccQ-Fluor Reagent Diluent was transferred to a vial containing AccQ-Fluor Reagent powder. This closed vial was mixed by vortexing for 10 s and heated on a water bath at 55°C until is dissolved (reconstituted AccQ-Fluor reagent). The 10 mL of filtered sample was mixed with 70 mL of AccQ-Fluor borate buffer, and then the mixed solution was vortexed briefly. The 20 mL of reconstituted AccQ-Fluor reagent added to the mixed solution and then mixed by vortexing for several seconds. This mixed solution was heated on a water bath at 55°C for 10 min (derivatives). The derivatives were analyzed using HPLC (Ultimate 3000RS, Thermo Fisher Scientific Inc., USA). With regard to the analytical conditions for HPLC, a Waters-AccQ-Tag Ultra C18 column (2.1×100 mm, 1.7 μm particles, Waters Co., USA) was utilized. Mobile phase consisted of solvent A (10% AccQ-Tag Eluent A concentrate) and solvent B (100% AccQ-Tag Eluent B concentrate) with gradient mode; 0-0.54 min: 99.9% solvent A and 0.1% solvent B, 0.54-5.74 min: 90.9% solvent A and 9.1% solvent B, 5.74-7.74 min: 78.8% solvent A and 21.2% solvent B, 7.74-9.04 min: 40.4% solvent A and 59.6% solvent B, 9.04-10.0 min; 10% solvent A and 90% solvent B, 10.0-13.0 min: 99.9% solvent A and 0.1% solvent B. The flow rate of the mobile phase was 0.7 mL/min and the injection volume was 10 μL. The column temperature was maintained at 35°C and the detection was monitored at a wavelength of 260 nm. The peaks of the individual amino acid were identified using the retention times for standards: Amino acid standard, L-glutamin, L-asparaging, L-tryptophan, and GABA (Sigma), and the concentration was calculated using the area for each peak.

Carnosine and anserine content

The contents of carnosine and anserine were determined using the method described by Mora *et al*. (2007). Meat sample (2.5 g) was homogenized with 7.5 mL of 0.01 N HCl at 1,130 *g* for 1 min (T25b). The homogenate was centrifuged at 17,030 *g* for 15 min (HM-150IV, Hanil Co., Ltd., Korea), and the supernatant (250 mL) was mixed with 750 mL acetonitrile. After storage at 4°C for 20 min and centrifugation at 17,030 *g* for 10 min (HM-150IV, Hanil), the supernatant was filtered through a 0.2 μm PVDF syringe filter (Whatman) and injected into a high-pressure liquid chromatography (HPLC) column equipped with a Waters 1525 pump and a Waters 717 plus autosampler (Millipore Co-Operative, USA). An Atlantis HILIC silica column (4.6×150 mm, 3 μm, Waters) was used. A diode array detector (Waters 2487, Millipore Co-Operative, USA) was used at 214 nm to measure creatine, carnosine, and anserine contents. The mobile phase A contained 0.65 mM ammonium acetate in water/acetonitrile (25:75, v/v, pH 5.5) and the B contained 4.55 mM ammonium acetate in water/acetonitrile (70:30, v/v, pH 5.5). The mobile phase B was supplied at 1.2 mL/min for 16 min with a linear gradient (0% to 100%). The content of compounds was calculated by using standard curve of each compound. Standards (carnosine and anserine) were obtained from Sigma-Aldrich (USA).

Nucleotides and their degraded compounds

The meat samples (5 g) were mixed with 25 mL of 0.7 M perchloric acid and centrifuged for 1 min at 1,130 *g* to extract nucleic acids. The extracted nucleic acids were then centrifuged for 15 min at 2,090 g and filtered through a Whatman No.4 filter paper (Whatman). The supernatant was then adjusted to pH 7 with 5 N KOH. The pH-adjusted supernatant was placed in a volumetric flask and made up to a volume of 100 mL with 0.7 M perchloric acid (pH 7). After 30 min of cooling, it was centrifuged at 1,130 *g* (4°C) and the supernatant was filtered through a 0.2 μm PVDF syringe filter (Whatman). The filtrate (5 mL) was analyzed using HPLC (ACME 9000, Younglin Instruments Inc., Korea). With regard to the analytical conditions for HPLC, a Waters-Atlantis dC18 RP column (4.6×250 mm, 5 μm particles, Waters Co., USA) was utilized, with a mobile phase of 0.1 M trimethylamine in 0.15 M acetonitrile (pH 7.0). The flow rate of the mobile phase was 1.0 mL/min and the injection volume was 10 μL. The column temperature was maintained at 35°C and the detection was monitored at a wavelength of 260 nm. The peaks of the individual nucleotides were identified using the retention times for standards: hypoxanthine, inosine, inosine-5'-phosphate (IMP), guanosine-5'-phosphate (GMP) (Sigma), and the concentration was calculated using the area for each peak.

Texture properties and shear force analysis

Pork loins were individually vacuum-packaged in a low-density polyethylene/nylon vacuum bags (20×15 cm). The

packaged pork loins were cooked in a 75°C water bath for 20 min and then cooled in tab water for 10 min.

The analysis of texture properties of cooked pork loin were conducted by two bite system using a Texture Analyzer (Model A-XT2, Stable Micro Systems Ltd., UK) with a 70 mm compression probe attachment. The cooked pork loin (2×2×1.5 cm) underwent two cycles of 70% compression with a test speed of 2 mm/s. Texture characteristics of cooked pork loin were expressed as hardness, springiness, cohesiveness, chewiness, gumminess, and resilience.

Shear force of cooked pork loin was determined using a Texture Analyzer (Model TA-XT2) with a Warner-Bratzler-blade attachment. Cooked pork loin was cut into 1 cm of diameter with 3 cm of length. Cross-sections of pork lone were placed at middle to the blade and sheared perpendicularly to the muscle fiber orientation. Crosshead speed was 2 mm/s and full-scale load was 50 kg.

Sensory evaluation

Sensory evaluation of normal and dry aged meats were implemented using a group consisting of thirty two panels who have experience in sensory test of meat and meat product. Each meat sample was cooked at 180°C for 3 min using electric steam oven (EON-C305CSM, Tongyang Magic Co., Korea) and cut regularly. The scoring of each sample was done on a single sheet using a 9-point hedonic scale (1 = extremely dislike, 9 = extremely like). The sensory parameters scored were color, flavor, taste, texture, and acceptability.

Statistical analysis

Data were analyzed using the PROC GLM procedure of SAS software (version 9.3, SAS Institute Inc., USA) in a complete randomized design. The experimental unit was the *Longissimus lumborum* muscle from half carcass. The statistical model for parameters of meat quality included the effect of dry aging as a main effect, and carcasses and panelists for sensory analysis as covariates. Specific comparisons were performed by Tukey's multiple range test when the main effect was significant. Results are reported as least square mean values and standard error of the least square means (SEM). Statistical significance was considered at $p<0.05$.

Result and Discussion

Total aerobic bacteria and lactic-acid bacteria

The total number of aerobic bacteria and lactic-acid bacteria in each pork loin is shown in Table 1. There was no significant difference in total aerobic bacterial count between control and dry aged pork loin ($p>0.05$). The dried surface of dry-aged meats along with low temperature in aging room retard the proliferation of aerobic bacteria (Campbell *et al*., 2001); dry aging did not affect total aerobic bacteria in pork loin. Lactic-acid bacteria were not detected in both the controls and the dry-aged pork loins.

Table 1. Total aerobic and lactic acid bacteria (Log CFU/g) of control and dry-aged pork loin

	Treatment		SEM[1]
	Control	Dry aged	
Total microbial counts	5.10	4.96	0.082
Lactic-acid bacteria	ND[2]	ND	

[1]Standard errors of the least square means (n=10).
[2]ND: Not detected.

Proximate composition

The proximate composition of control and dry-aged pork loin is presented in Table 2. The moisture content of dry-aged pork loin was significantly lower than that of the control ($p<0.05$). Campbell *et al*. (2001) reported that the moisture of meat evaporated after dry aging because of exposure to air. The dry-aged pork loin had significantly high protein and ash content compared to that of the control, because of the relatively low moisture content ($p<0.05$). However, there was no significant difference in fat content between the dry-aged pork loin and the control. These results were in accordance with those of a previous study (Juárez *et al*., 2011; Lee *et al*., 2015). Juárez *et al*. (2011) reported that dry aged pork loin for 14 d resulted in the decrease of moisture content, increase of protein content, and no difference in fat content. Lee *et al*. (2015) also found that dry aging for 21 d results in decrease of moisture content and increase in protein and ash contents

Table 2. Proximate composition (%) of control and dry-aged pork loin

	Treatment		SEM[1]
	Control	Dry-aged	
Moisture	70.64[a]	68.21[b]	0.395
Crude fat	6.12	6.33	0.378
Crude protein	22.28[b]	23.56[a]	0.158
Crude ash	0.99[b]	1.24[a]	0.076
pH	5.54[b]	5.66[a]	0.012
Cooking loss	34.34[a]	28.16[b]	0.219

[1]Standard errors of the least square means (n=10).
[a,b]Values with different letters within the same column differ significantly ($p<0.05$).

in strip loin of beef.

pH and cooking loss

The pH and cooking loss of pork loin were measured (Table 2). The pH of dry-aged pork loin was higher than that of the control ($p<0.05$). Generally, pH of meat increases after storage because of protein degradation caused by proteinase released from microorganisms with increased proliferation during storage period (Agunbiade *et al*., 2010). However, in the present study, the number of total aerobic bacteria of pork loin was not changed after dry aging. Therefore, it is considered that the increase of pH in dry-aged pork loin may be due to the increase of basic free amino acids that were generated during the degradation of proteins by endogenous proteinases in the meat. Previous studies reported that the pH of beef strip loin was increased with dry ageing period (Ahnström *et al*., 2006; Lee *et al*., 2015).

Dry-aged pork loin had significantly low cooking loss compared to the control ($p<0.05$). The low water content in the dry-aged pork loin compared with that of control might be one of reasons for low cooking loss of dry-aged pork loin. The higher pH of the dry-aged pork loin than control was found in the present study. Lee *et al*. (2015) reported that dry-aged strip loin of beef had low cooking loss with high pH compared to that of the unaged strip loin. Once the pH decreases to the isoelectric point of myofibrillar proteins, the net charge between myofibrillar proteins was decreased and consequently, the water-holding capacity of meat was decreased (Huff-Lonergan and Lonergan, 2005). In addition, Kristensen and Purslow (2001) suggested that the degradation of cytoskeletal proteins while aging decreased the rigor-induced shrinkage of myofibrils, which enabled extracellular water to flow into the muscle cell and consequently increased water-holding capacity of meat. Therefore, dry-aged pork loin showed low cooking loss in the present study.

Free amino acids and dipeptides

After dry aging of pork loin, there was a significant increase in most free amino acids such as Ala, Arg, Asn, GABA, Gln His, Ile, Leu, Met, Phe, Pro, Ser, Thr, Try, Tyr, and Val contents ($p<0.05$, Table 3). However, there was no significant difference in Cys and Gly content between the control and dry-aged pork loins, and Asp and Lys content were significantly lower in the dry-aged pork loin than in the control ($p<0.05$). Although the contents of some free amino acids are maintained or decreased in pork loin after dry aging, the amount of total free amino acid was increased in dry-aged pork loin by as much as 73% ($p<0.05$). Moya *et al*. (2001) found that free amino acid content increases in pork loin after aging. Koutsidis *et al*. (2008) reported the increase of free amino acid content in beef loin by as much as 80% after aging for 21 d. The muscle contains various proteinase and peptidases that degrade myofibrillar and cytoskeletal proteins in meat to peptides and free amino acids during postmortem aging (Laville *et al.*, 2009; Toldrá *et al*., 1995). Free amino acid is an important flavor precursor that has specific taste and produces various aroma compounds through the Maillard reaction and Strecker degradation in cooked meat (Koutsidis *et al*., 2008; Mottram, 1998). The free amino acid contents that increased in the present study after dry aging have taste characteristics such as sweet (Ala, Ser, and Thr), bitter (Arg, His, Ile, Leu, Met, Phe, and Try), sweet with after bitter taste (Val and Pro), and salty-bitter (Gln) (Fukunaga *et al.,* 1989; Mau and Tseng, 1998). Although some amino acids generate an unpleasant taste, free amino acids

Table 3. Free amino acids and histidine dipeptides content (mg/100 g) of control and dry-aged pork loin

	Treatment		SEM[1]
	Control	Dry-aged	
Free amino acids			
Ala	7.14[b]	24.10[a]	0.537
Arg	802.84[b]	1336.22[a]	26.730
Asn	3.30[b]	16.79[a]	0.374
GABA	12.08[b]	23.09[a]	0.604
Gln	2.05[b]	5.53[a]	0.270
His	3.13[b]	13.54[a]	0.398
Ile	4.60[b]	18.90[a]	0.753
Leu	12.44[b]	44.64[a]	0.937
Met	5.0 [b]	17.56[a]	0.908
Phe	7.84[b]	34.20[a]	0.803
Pro	57.35[b]	106.33[a]	2.290
Ser	9.06[b]	34.74[a]	0.736
Thr	8.27[b]	29.89[a]	0.549
Try	0.15[b]	0.66[a]	0.122
Tyr	19.94[b]	79.70[a]	2.343
Val	3.98[b]	17.37[a]	0.374
Cys	9.54	9.83	0.494
Gly	172.51	178.40	4.710
Asp	18.10[a]	15.05[b]	0.472
Lys	0.20[a]	0.01[b]	0.023
Total	1159.55[b]	2006.56[a]	38.291
Dipeptides			
Anserine	26.47	26.34	0.262
Carnosine	182.40	185.83	2.053

[1]Standard errors of the least square means (n=10).
[a,b]Values with different letters within the same row differ significantly ($p<0.05$).

are important to generate pleasant aroma compounds in cooked meat (Koutsidis *et al*., 2008).

Carnosine and anserine are histidyl dipeptides that are widely distributed in the skeletal muscle and are known as bioactive compounds that function as antioxidants and neurotransmitters (Peiretti *et al*., 2011; Tian *et al*., 2007). However, they also act as precursors for bitter taste (Macleod, 1994). In the present study, there is no significant difference in carnosine and anserine contents between control and dry-aged pork loin. Moya *et al*. (2001) found no change in carnosine and anserine content in pork loin after aging, and reported that no proteases could hydrolyze them in postmortem meat.

Nucleotide and their degraded compounds

GMP and IMP in meat contribute to umami taste of meat as flavor precursors (Koutsidis *et al*., 2008). Hypoxanthine is closely associated with the bitter taste of meat (Tikk *et al*., 2006). However, the GMP and IMP content in pork loin were significantly decreased, whereas the inosine and hypoxanthine content in pork loin were significantly increased after dry aging in the present study ($p<0.05$, Table 4). This result was because of the enzymatic degradation of nucleotides such as GMP and IMP to nucleosides, followed by further degradation to purine and ribose. Yano *et al*. (1995) reported that the degradation of IMP resulted in the accumulation of its enzymatic breakdown products, such as inosine, hypoxanthine, and ribose in meat. Ribose is a type of reducing sugar that plays an important role in producing aromas by the Maillard reaction and Strecker degradation with free amino acids (Mottram, 1998). However, the reducing sugar content of dry-aged pork loin was not significantly different from that of control in the present study (data not shown). The results suggest that there was no improvement in flavor caused by nucleotides and their degraded products in dry-aged pork loin.

Texture property and shear-force

The hardness, cohesiveness, gumminess, chewiness, and resilience were significantly decreased in dry-aged pork loin compared to that in control ($p<0.05$, Table 5). In contrast, springiness of dry-aged pork was significantly increased ($p<0.05$). In addition, dry-aged pork loin showed lower shear-force than the control ($p<0.05$). These results suggested that dry-aged pork loin was tender than control. Meat tenderness is improved with the structural degradation of myofibrils caused by degradation of myofibrillar and cytoskeletal proteins after aging (Nowak, 2011). A previous study reported the degradation of desmin and integrin in pork loin after postmortem aging (Yin *et al*., 2014). In addition, Cruzen *et al*. (2014) found the troponin-T and titin degradation in beef during the aging period.

Table 4. Nucleotide and degraded compound content (mg/100 g) of control and dry-aged pork loin

	Treatment		SEM[1]
	Control	Dry-aged	
Guanosine 5'-monophosphate	4.34[a]	2.55[b]	0.127
Inosine 5'-monophosphate	238.92[a]	90.69[b]	4.313
Hypoxanthine	8.47[b]	27.40[a]	0.682
Inosine	66.24[b]	129.82[a]	1.599

[1]Standard errors of the least square means (n=10).
[a,b]Values with different letters within the same row differ significantly ($p<0.05$).

Table 5. Texture properties and shear force of control and dry-aged pork loin

	Treatment		SEM[1]
	Control	Dry-aged	
Hardness (kg)	35.57[a]	27.13[b]	0.845
Cohesiveness	0.51[a]	0.48[b]	0.152
Springiness	0.50[b]	0.57[a]	0.009
Gumminess	18.34[a]	13.22[b]	0.487
Chewiness	9.14[a]	7.60[b]	0.315
Resilience	0.19[a]	0.15[b]	0.003
Shear force (kg)	4.64[a]	2.50[b]	0.282

[1]Standard errors of the least square means (n=10).
[a,b]Values with different letters within the same row differ significantly ($p<0.05$).

Table 6. Sensory properties of control and dry-aged pork loin

Sensory parameters	Treatment		SEM[1]
	Control	Dry-aged	
Color	4.78[b]	5.19[a]	0.096
Taste	4.19[b]	5.36[a]	0.152
Flavor	4.27[b]	5.20[a]	0.160
Texture	4.39[b]	5.45[a]	0.168
Acceptability	4.22[b]	5.44[a]	0.157

[1]Standard errors of the least square means (n=64).
[a,b]Values with different letters within the same row differ significantly ($p<0.05$).

Sensory evaluation

The scores for sensory parameter of cooked pork loin are shown in Table 6. Dry-aged pork loin received higher scores in color, taste, flavor, and texture than control ($p<0.05$). Consequently, the score for overall acceptability was significantly higher in dry-aged pork loin than control ($p<0.05$), suggesting that dry aging improved palatability of pork loin. Juárez *et al*. (2011) found improvement in tenderness, juiciness, and flavor in pork after dry

aging. Campbell *et al*. (2001) reported that dry aging increased the tenderness and juiciness of beef with the increase of aged flavor.

Conclusion

Dry aging of pork loin at 2°C with 80% RH for 40 d resulted in the change of the physicochemical and sensorial quality of pork loin. The protein content of pork loin increased with moisture loss. Cooking loss of pork loin decreased. In addition, free amino acid content as a flavor precursor increased, although the content of IMP and GMP decreased. Hardness and shear force of cooked pork loin decreased. Sensory panels gave dry-aged pork loin high scores for color, taste, flavor, and texture due to physicochemical change in dry-aged pork loin. The data in the present study suggest that dry aging improved the quality of pork loin. Therefore, we concluded that the quality of pork loin could be improved by dry aging in terms of tenderness and palatability.

Acknowledgements

This study was financially supported by research fund of Chungnam National University.

References

1. Agunbiade, S. O., Akintobi O. A., and Ighodaro, O. M. (2010) Some biochemical and organoleptic changes due to microbial growth in minced beef packaged in alluminium polyethylene trays and stored under chilled condition. *Life Sci. J.* **7**, 47-51.
2. Ahnström, M. L., Seyfert, M., Hunt, M. C., and Johnson D. E. (2006) Dry aging of beef in a bag highly permeable to water vapour. *Meat Sci*. **73**, 674-679.
3. AOAC (2005) Official methods of analysis (18th revised ed.), Washington, DC: Association of Official Analytical Chemists.
4. Blanchard, P. J., Willis, M. B., Warkup C. C., and Ellis, M. (2000) The influence of carcass backfat and intramuscular fat level on pork eating quality. *J. Sci. Food Agric.* **80**, 145-151.
5. Caballero, B., Sierra, V., Olivaìn, M., Vega-Naredo, I., Tomás-Zapico, C., Alvarez-Garciìa, O., Tolivia, D., Hardeland, R., Rodriìguez-Colunga, M. J., and Coto-Montes, A. (2007) Activity of cathepsins during beef aging related to mutations in the myostatin gene. *J. Sci. Food Agric.* **87**, 192-199.
6. Campbell, R. E., Hunt, M. C., Levis, P., and Chambers, E. (2001) Dry-aging effects on palatability of beef longissimus muscle. *J. Food Sci*. **66**, 196-199.
7. Chen, L., Feng, X. C., Zhang, Y. Y., Liu, X. B., Zhang, W. G., Li, C. B., Ullah, N., Xu, X. L. and Zhou, G. H. (2015) Effects of ultrasonic processing on caspase-3, calpain expression and myofibrillar structure of chicken during post-mortem ageing. *Food Chem.* **177**, 280-287.
8. Cruzen, S. M., Paulino, P. V. R., Lonergan, S. M., and Huff-Lonergan, E. (2014) Postmortem proteolysis in three muscles from growing and mature beef cattle. *Meat Sci.* **96**, 854-861.
9. DeVol, D. L., McKeith, F. K., Bechtel, P. J., Novakofski, J., Shanks, R. D., and Carr, T. R. (1988). Variation in composition and palatability traits and relationships between muscle characteristics and palatability in a random sample of pork carcasses. *J. Anim. Sci.* **66**, 385-395.
10. Fukunaga, T., Koga, K., Maita, Y., and Matsuoka, S. (1989) Free amino acid, carnosine and 5'-inosinic acid contents in the breast and leg meats from the cross and tripe-cross chickens of Satsuma native fowl. *Bull. Fac. Agric. Kagoshima Univ.* **39**, 223-232.
11. Gruber, S. L., Tatum, J. D., Scanga, J. A., Chapman, P. L., Smith G. C., and Belk, K. E. (2006) Effects of postmortem aging and USDA quality grade on Warner-Bratzler shear force values of seventeen individual beef muscles. *J. Anim. Sci.* **84**, 3387-3396.
12. Huff-Lonergan, E. and Lonergan, S. M. (2005) Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. *Meat Sci.* **71**, 194-204.
13. Juárez, M., Cainea, W. R., Dugana, M. E. R., Hidirogloub, N., Larsena, I. L., Uttaroa, B., and Aalhus, J. L. (2011) Effects of dry-ageing on pork quality characteristics in different genotypes. *Meat Sci.* **88**, 117-121.
14. KMTA (Korea Meat Trade Association) (2014) Meat consumption per person in Korea. Available from http://www.kmta.or.kr/html/sub6-1.html?scode=6
15. Koohmaraie, M. (1994) Muscle proteinases and meat aging. *Meat Sci*. **36**, 93-104.
16. Koutsidis, G., Elmore, J. S., Oruna-Concha, M. J., Campo, M. M., Wood, J. D., and Mottram, D. S. (2008) Water-soluble precursors of beef flavour. Part II: Effect of post-mortem conditioning. *Meat Sci*. **79,** 270-277.
17. Kristensen, L. and Purslow, P. P. (2001) The effect of ageing on the water-holding capacity of pork: Role of cytoskeletal proteins. *Meat Sci.* **58**, 17-23.
18. Laville, E., Sayd, T., Morael, M., Blinet, S., Chambom, C., Lepetit, J., Renand, G., and Hocquette J. F. (2009) Proteome changes during meat aging in tough and tender beef suggest the importance of apoptosis and protein solubility for beef aging and tenderization. *J. Agr. Food Chem*. **57,** 10755-10764.
19. Lee, C. W., Lee, S. H., Min, Y. J., Lee, S. K., Jo, C., and Jung, S. (2015) Quality improvement of strip loin from Hanwoo with low quality grade by dry aging. *Korean J. Food Nutr.* **28**, 415-421.
20. Macleod, G. (1994) The flavor of beef: In the flavor of meat and meat product, Blackie, London, pp. 4-73
21. Maltin, C., Balcerzak, D., Tilley, R., and Delday M. (2003) Determinants of meat quality: Tenderness. *Proc. Nutr. Soc.* **62**, 337-347.
22. Mau, J. L. and Tseng, Y. H. (1998) Nonvolatile taste components of three strains of *Agrocybe cylindracea*. *J. Agr. Food Chem.* **46**, 2071-2074.
23. Mora, L., Sentandreu, M. A., and Toldra, F. (2007) Hydrophi-

lic chromatographic determination of carnosine, anserine, balenine, creatine, and creatinine. *J. Agr. Food. Chem.* **55**, 4664-4669.
24. Mottram D. S. (1998) Flavour formation in meat and meat products; A review. *Food Chem.* **62**, 415-424.
25. Moya, V. J., Flores, M., Aristoy, M. C., and Toldrá, F. (2001) Pork meat quality affects peptide and amino acid profiles during the ageing process. *Meat Sci.* **58**, 197-206.
26. Nowak, D. (2011) Enzymes in tenderization of meat - The system of calpains and other systems - A review. *Pol. J. Food Nutr. Sci.* **61**, 231-237.
27. Parrish, F. C., Boles, J. A., Rust, R. E., and Olson. D. G. (1991) Dry and wet aging effects on palatability attributes of beef loin and rib steaks from three quality grades. *J. Food Sci.* **56**, 601-603.
28. Peiretti, P. G., Medanab, C., Visentinc, S., Giancottib, V., Zuninod, V., and Meinerid, G. (2011) Determination of carnosine, anserine, homocarnosine, pentosidine and thiobarbituric acid reactive substances contents in meat from different animal species. *Food Chem.* **126**, 1939-1947.
29. Shackelford, S. D., Wheeler, T. L., Meade, M. K., Reagan, J. O., Byrnes, B. L., and Koohmaraie, M. (2001) Consumer impressions of tender select beef. *J. Anim. Sci.* **79**, 2605-2614.
30. Sitz, B. M., Calkins, C. R., Feuz, D. M., Umberger, W. J., and Eskridge K. M. (2006) Consumer sensory acceptance and value of wet-aged and dry-aged beef steaks. *J. Anim. Sci.* **84**, 1221-1226.
31. Smith, R. D., Nicholson, K. L., Nicholson, J. D. W., Harris, K. B., Miller, R. K., Griffin, D. B., and Savell, J. W. (2008) Dry versus wet aging of beef: Retail cutting yields and consumer palatability evaluations of steaks from US Choice and US Select short loins. *Meat Sci*. **79**, 631-639.
32. Tian, Y., Xie, M., Wang, W., Wu, H., Fu, Z., and Lin, L. (2007) Determination of carnosine in black-bone silky fowl (*Gallus gallus domesticus* Brisson) and common chicken by HPLC. *Eur. Food Res. Technol.* **226**, 311-314.
33. Tikk, M., Tikk, K., Tørngren, M. A., Meinert, L., Aaslyng, M. D., Karlsson, A. H., and Andersen, H. J. (2006) Development of inosine monophosphate and its degradation products during aging of pork of different qualities in relation to basic taste and retronasal flavor perception of the meat. *J. Agr. Food Chem.* **54**, 7769-7777.
34. Toldrá, F., Flores, M., and Aristoy, M. C. (1995) Enzyme generation of free amino acids and its nutritional significance in processed pork meats. Proceedings of the 8th International Flavor Conference, Amsterdam, pp. 1303-1322.
35. Warren, K. E. and Kastner, C. L. (1992) A comparison of dry-aged and vacuum-aged beef strip loins. *J. Muscle Foods* **3**, 151-157.
36. Yano, Y., Kataho, N., Watanabe, M., Nakamura, T., and Asano, Y. (1995) Evaluation of beef aging by determination of hypoxanthine and xanthine contents: Application of a xanthine sensor. *Food Chem.* **52**, 439-445.
37. Yin, Y., Zhang, W. G., Zhou, G. H., and Guo, B. (2014) Comparison of protein degradation, protein oxidation, and μ-calpain activation between pale, soft, and exudative and red, firm, and nonexudative pork during postmortem aging. *J. Anim. Sci.* **92**, 3745-3752.