Effect of pig breed and processing stage on the physicochemical properties of dry-cured loin

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Abstract

This study investigated the effect of pig breeds on the quality characteristics of dry-cured loins according to the processing stage. Physicochemical properties of 20 dry-cured processed loins with the different pig breeds (Berkshire vs Landrace × Yorkshire × Duroc (LYD; n=10)) and different processing stages (raw, curing, dry-ripened 15 day and 30 day) were analyzed. The pig breed influenced moisture content and pH with values of 59% and 53%, and 6.17 and 5.94, for Berkshire and LYD, respectively, at day 30. Dry-cured loins made with Berkshire showed higher hardness and lower cohesiveness than that of the LYD ($p<0.05$). Redness and yellowness were higher for Berkshire than LYD ($p<0.05$). Lipid oxidation and lightness did not affect by pig breed during processing stages ($p>0.05$). However, sulfhydryl content was significantly higher in Berkshire compared to the LYD after dry-ripened for 15 days ($p<0.05$). The concentration of total free amino acids and fatty acids was higher for Berkshire during all processing stages ($p<0.05$). Berkshire may be better quality due to its high moisture content and pH compared to the LYD.

Keywords: Pig breed; Processing stage; Dry-cured loin; Oxidative phenomena; Physicochemical properties

1. Introduction

Dry-cured meat product has created from a long stage ago, and there are a wide variety of styles. The characteristics of the final product have been determined by the type of raw meat and chloride salt. Regarding raw material, Cilla et al. (2006) have performed about the effect of Duroc line sire on dry-cured ham. Armenteros et al. (2012) have conducted to replacement of NaCl by other chloride salts. In addition, by monitoring the change in lipid or a protein according to the processing stage, it has been discussed in related to the texture properties or volatile compounds of dry-cured ham (Harkouss et al., 2015; Pérez-Santaescolástica et al., 2018). Dry-cured loin takes third in consumer preferences in Spain and is well accepted (Aliño et al., 2009). The typical manufacturing process is similar to that of the ham, but the time required for each stage is different, and the processing period of dry-cured loin is shorter than the dry-cured ham (50 days vs 18 months) (Abellán et al., 2018).

Oxidative reaction in dry-cured meat is an important factor in the determination of quality characteristics of dry-cured meat. During processing, proteins and lipids undergo both oxidation and degradation of myofibrillar proteins or triacylglycerides and phospholipids, respectively, which produce different chemical compounds related to taste (such as free amino acid) or flavor (such as free fatty acid) (Ripollés et al., 2011; Toldra 2006). Also, lipid oxidation can affect the production of numerous volatile compounds due to various decomposition mechanisms, and these compounds have a unique flavor of dry-cured ham (Jin et al., 2010). However, some previous studies have reported that breakdown and oxidation are not particularly relevant in the manufacture of dry-cured ham (Jin et al., 2010; Muriel et al., 2007). Thus, the relationship between breakdown and oxidation in dry-cured meat still need to discuss.

Berkshire pigs are a breed of pig originating from the English county of Berkshire that is bred and raised in several parts of the world. The Berkshire pig is not all black but has white, including white socks from the "knee" down and typically a white blaze on its snout (Wikipedia, 2019). This breed has remarkable water holding capacity evaluated by cooking loss and drip loss (Lee et al, 2012; Suzuki et al., 2003). In Korea, the most commonly used pork in the commercial market is crossbred pigs, and their characteristics are fast growth, small size, and high meat quantity. The characteristics in pig breeds for the production of crossbred pig followed: Landrace is high daily gain, Yorkshire is thin back fat, and Duroc is high formation of intramuscular fat (Kang et al., 2011). For the reason of production cost based on efficiency, purebred pigs are not suitable in industry. The previous studies have been reported that the crossbred pig has poor meat quality than purebred pigs (Ryu et al., 2008). Ryu et al. (2008) found that most of the samples from Berkshire pigs turned out normal pork (red, firm and non-exudative, RFN). In contrast, approximately 60% of the samples from the Landrace pigs turned out abnormal pork (pale, soft and exudative, PSE; reddish-pink, soft and exudative, RSE; dark, firm and dry, DFD). Also, Subramaniyan et al. (2016) showed that physicochemical characteristics of Berkshire pigs are significantly greater than the LYD, and the authors mentioned that this is a very desirable characteristic for consumers. In summary to the reference, Berkshire has reported higher water holding capacity and palatability than LYD. Thus, it is necessary to compare with LYD how these raw meat characteristics affect the quality of dry-cured loin.

For these reasons, the hypothesis of this study is that the quality characteristics of dry-cured loin may be influenced by pig breeding and processing stage. Therefore, the purpose of this study was to determine the effect of pig breed according to the processing stage of dry-cured loin. In addition, oxidative changes on the quality characteristics of dry-cured loin were also investigated.

2. Materials and methods

2.1. Experimental design and dry-cured loin preparation

Animal replication and processing batch effect were randomized for consideration on only experimental effect (breed and processing stage). Animals were reared according to next paragraph, and twenty pigs (Berkshire = 10, LYD = 10 and; n = 10) were evaluated for this study. Also, the dry-cured loin processing was performed 5 times on different day in order not to consider the batch effect.

The pigs were raised in the different pen on the same farm and fed the same diet following the commercial production system. The pigs were transferred to a local slaughter house and slaughtered by traditional neck cutting when their live weight reached between 110 kg to 115 kg. The carcasses were hung in a chilling room at 0~2℃ for 24 h after slaughtering. The pork loins were used deboning and removed the backfat and connective tissue. The pair of pork loins from each pig were removed at 3 cm at both ends and divided in half, and randomly assigned to each processing stage. The trimmed pork loin was rubbed by hand for 10 min with 3.5% purified sodium chloride (99.9%, w/w) and left for 4 days at 4℃ and 80 ± 5% room humidity (RH) in salting the bath. After the curing stage, the surface of cured loin was rinsed with tap water and removed moisture with the paper towel. The first drying-ripening stage was performed for 15 days in an artificial environment chamber at 15℃ and 80 ± 5% RH, and secondary the drying-ripening stage was carried for 15 days at 12℃ and 65 ± 5% RH. After drying-ripening, the dry-cured loins were vacuum-packed and stored at -80℃ till further analysis.

2.2. Analytical methods

2.2.1. Moisture content and pH

Moisture content was analyzed in duplicate by weight losses after 24 h at 103 ± 1℃ (AOAC, 2012). The results were expressed as the percentage of weight. The pH was determined directly with a pH meter (S20 SevenEasy^{TM}, Greifensee, Switzerland). The measurement was taken three times and calibrated with pH 7.00, 4.01, and 9.21.

2.2.2. *Texture profile analysis* (TPA)

TPA was carried out by EZ-SX (Shimadzu corp., Kyoto, Japan) at room temperature. Two cubes (50 mm × 30 mm × 25 mm, length × width × height) were analyzed, and it was taken at the central portion of each loin. Each section was tested with four replications. The samples were placed with the muscle fiber parallel to the compression plate surface and compressed twice to 50% of their original height with a time interval of 0 s between the two compressions. Force-time curves were recorded with a 500 N load cell applied at a crosshead speed of 100 mm/min. The TPA parameters were obtained using the software package and calculated by Bourne (1982).

2.2.3. Instrumental color

The instrumental color was measured ten times for each sample by a colorimeter (CR-400, Konica Minolta, Tokyo, Japan). CIE (Commission International del'éclairage) L^* (lightness), a^* (redness), b^* (yellowness), C^* (chroma), and hº (hue angle) values were determined with D65 illuminant and 2° standard observer. The instrument was calibrated using a standard white plate (Y = 81.2; x = 0.3191; y = 0.3263). The data were obtained from the average of each measured value.

2.2.4. TBARS and sulfhydryl content

The TBARS in dry-cured loin was determined based on the method of Cherian et al. (2007) with some modifications. About 3 g of samples were homogenized with 27 mL of 3.86% perchloric acid. The homogenates were kept at room temperature for 1 h and then centrifuged at 2000 × *g* for 10 min. The supernatants were filtered through Whatman filter paper No. 1, and the filtrates were mixed with 20 mM TBA solution (1:1, v/v). Then, the mixture was kept in a dark condition for 15 h at room temperature and then read at 531 nm using a spectrophotometer (Cary 60 UV–Vis, Agilent Technologies, CA, USA). The measured value was expressed as mg MDA/kg sample.

Sulfhydryl was measured following the method of Vossen and De Smet (2015) with some modifications. Two gram samples were homogenized with 25 mL of 1% SDS in 0.10 M Tris buffer. The homogenates were incubated in a water bath for 30 h at 80°C. After cooling at room temperature, the homogenates were centrifuged at 7000 × *g* for 20 min. For the sulfhydryl concentration, 2 mL of 0.1 M Tris buffer (pH 8.0) and 0.5 mL of 10 mM DTNB in 0.1 M Tris buffer were mixed with 0.5 mL of filtered supernatant. For protein concentration, 0.5 mL of filtered supernatant was added to 2.5 mL of 0.1 M Tris buffer. Again, 0.5 mL of 5% SDS in Tris buffer (pH 8.0), 0.5 mL of 10 mM DTNB, and 2.0 mL of 0.1 M Tris buffer were mixed to prepare a blank solution. All mixtures were kept for reaction in the dark room at 4°C for 30 min. The absorbance of sulfhydryl concentration in dry-cured loin was measured by spectrophotometer at 412 nm. The sulfhydryl concentration was calculated using the Lambert-Beer equation of $^{\varepsilon}{}_{412} = 14{,}000\ \mathrm{M}^{-1}\ \mathrm{cm}^{-1}$ and expressed as nmol sulfhydryl/mg protein. The protein concentration in dry-cured loin was measured at 280 nm and calculated based on a bovine serum albumin standard curve.

2.2.5. Fatty acid analysis

The mixture of 5 g of the sample and 1 mg of undecanoic acid as internal standard were homogenized with 25 mL methanol/chloroform solution (methanol:chloroform, 1:2, v/v), and total lipids in the intramuscular were extracted according to the Folch et al. (1957). The solvent in the lipid extract has evaporated at room temperature for 2 h in dark condition. For saponification, the extracted lipids were dissolved with 2 mL methylene chloride, and then 200 μL was transferred to a glass vial and boiled with 1 mL of 0.5 N NaOH at 85℃ for 10 min. According to Metcalfe et al. (1966), the glass vial was cooled at room temperature and boiled with 1 mL of BF3-methanol solution at 85℃ for 10 minutes for methylation. After methylation, the addition of 3 mL hexane and 8 mL DW were added into the glass vial and vortexed for 10 s and centrifuged at 1,000 rpm for 5 min. The 1 mL upper layer was taken for analysis. The gas chromatography running conditions were determined by Lorenzo et al. (2015) with some modifications. The split ratio was 1:10, and 1 μL of the solution was injected. Each peak was identified by comparing their retention times with those of certified standards (Supelco 37 component FAME mix). Separation and quantification of the FAMEs was carried out using a gas chromatograph (GC Agilent 6890 N; Agilent Technologies Spain, S.L., Madrid, Spain) equipped with a flame ionization detector and an automatic sample injector HP 7683, and using a Supelco SP-2560 capillary GC column (fused silica, 100 m × 0.25 mm × 0.2 μm). The chromatographic conditions were as follows: initial column temperature 120℃, maintaining this temperature for 5 min, programmed to increase at a rate of 5℃/min up to 200℃, maintaining this temperature for 2 min, then at 1℃/min up to 230℃, maintaining this temperature for 3 min. The injector and detector were maintained at 260 and 280℃, respectively. Nitrogen was used as the carrier gas at a constant flow-rate of 1.1 mL/min, with the column head pressure set at 35.56 psi, and the split ratio was 1:20. The results were calculated as compared to the peak area of the internal standard according to the relative quantification method, and expressed as mg fatty acid/g sample.

2.2.6. Free amino acid analysis

Free amino acids were analyzed using a method from Franco et al. (2010) with some modifications. Briefly, 10 g of sample was homogenized with 90 mL of DW and centrifuged at 2,000 × *g* for 10 min. The 10 mL of supernatant was mixed with 10% TCA solution for deproteinization and centrifuged at 10,000 × *g* for 10 min. The 5 mL of supernatant was mixed with 5 mL of hexane to remove lipid and taken to the lower layer (water layer) filtered through a 0.28 μm membrane filter. The filtrate was injected into an amino acid analyzer (Biochrome 30 plus, Biochrome, Cambourne, UK).

2.3. Statistical analysis

All data were expressed as mean values with a standard error of the means. The statistical model included pig breed and processing stage as fixed factors and animal replication and processing batch as random terms. An analysis of variance (ANOVA) using the ANOVA procedure of the SAS (SAS version 9.4, SAS Institute, Inc., USA) was performed for all variables considered. A Duncan's multiple range test was performed to compare the mean values at a significance level of $p<0.05$.

3. Results and discussion

3.1. Moisture content and pH values

The results for moisture content and pH are shown in Table 1. The range of moisture content was 59~73% in Berkshire and 52~73% in LYD. The moisture level before day 15 of drying-ripening as 73% was no difference between pig breeds ($p>0.05$). However, the Berkshire was significantly higher than that of the LYD on days 15 of drying-ripening ($p<0.05$). The differences in moisture content between the pig breeds were about 6% even at days 30 of dry aging. Also, it tended to significantly decrease with the processing stage, and LYD showed a higher reduction ($p<0.05$). In pH values, there was no difference in pH values at the raw meat. However, similar to the result of moisture content, there was significantly difference between pig breeds from day 15 of drying-ripening, and Berkshire and LYD were 6.17 and 5.94, respectively on day 30 of drying-ripening ($p<0.05$). Furthermore, the pH was significantly increased in all dry-cured loin as the processing stage progressed ($p<0.05$).

Seong et al. (2014) reported that there was no significant difference in moisture content between dry-cured ham of Berkshire and LYD and dry-cured ham of Berkshire showed a numerically higher moisture content of about 3% compared to those of LYD. However, these authors reported that dry-cured ham of Berkshire was about 10% lower in total weight loss than those of LYD. In addition, Berkshire reported lower drip loss compared to those of LYD, Yorkshire, Landrace and Duroc in raw meat (Lee et al., 2012; Ryu et al., 2008). Based on this, one hypothesis may be that due to greater water holding capacity of Berkshire, it may have a higher moisture content than LYD on the day 30 of drying-ripening. Moisture and pH are key factors in the manufacture of dry-cured meat product and have a great influence on the overall quality characteristics. In particular, it was found that these factors had a great influence on proteolysis and lipolysis through previous studies, and Rico et al. (1993) reported that the proteolytic enzymes cathepsin B and L were slightly affected by the decrease in salt and water activity, and showed the most optimal activity at pH 5.7. Also, Petrova et al. (2015) reported that triacylglycerol and phospholipids were hydrolyzed by lipolytic enzymes during the processing, and they were finally decomposed into free fatty acids, and the optimum pH range was different depending on the type of lipolytic enzyme.

3.2. Color values

The instrumental color parameters for dry-cured loin are shown in Table 2. Lightness was not significantly difference between pig breeds at the initial stage ($p>0.05$), but Berkshire had significantly higher lightness on day 30 of drying-ripening from the curing stage ($p<0.05$). The lightness of two pig breeds significantly decreased depending on the processing stage ($p<0.05$). At this stage, lightness decreased more for LYD compared to Berkshire. Redness was significantly difference between pig breeds from the beginning to day 30 of drying-ripening, excluding the curing stage ($p<0.05$). In the raw meat stage, redness of Berkshire and LYD was 5.81 and 5.20, respectively, the values gradually increased until the day 30 of dry ripening to 8.63 and 6.24, respectively. The dry-cured loin of Berkshire was about 2 higher than that of LYD ($p<0.05$). Contrary to lightness, it significantly increased with the processing stage ($p<0.05$), and Berkshire showed a greater lightness than LYD. The values of yellowness and chroma were significantly higher in Berkshire than in LYD at each stage, and significantly increased according to processing stage in all pig breeds ($p<0.05$). The hue angle was significantly higher for Berkshire from the beginning to the curing stage ($p<0.05$), but there were no significant differences between the pig breeds on day 30 of drying-ripening ($p>0.05$). Likewise, the lightness decreased significantly with the processing stage ($p<0.05$). Overall, Berkshire showed higher values for color parameters on day 30 of drying-ripening than LYD. In addition, there was a tendency to increase as processing progressed except for lightness.

A color has a great influence on basic product purchasing decisions alike technical characteristics and textural properties (Faustman and Cassens, 1990). Ryu et al. (2008) compared the meat quality of various pig breeds, and Berkshire reported higher redness and lower lightness than those of the LYD, Landrace, and Yorkshire, and these results were similar to our results. Lightness is correlated with water holding capacity, which was revealed through previous studies (Huff-Lonergan et al., 2002). In addition, the authors reported that drip loss and cooking loss are representative methods of measuring water holding capacity of meat and also reported a positive correlation with lightness and mentioned that this is closely related to pH. Therefore, a higher water holding capacity of Berkshire could be likely to result in relatively little leakage of water on the surface, resulting in reduced reflection during measurement and low lightness. In addition, a higher water holding capacity of Berkshire would have an effect on the amount of water evaporated over the processing stage. As a result, the higher moisture content of Berkshire would have a higher lightness. Redness of Berkshire was higher than those of LYD from the beginning, and this was maintained until day 30 of drying-ripening. This result may be due to differences in raw meat. In addition, the cured meat color forms NO-MetMb through a chemical reaction between myoglobin in meat and nitrate/nitrite, which is reduced to nitrosylmyoglobin in an anaerobic state, and at this stage, it has a red color (Suman and Joseph, 2013). Furthermore, increased nitrosylmyoglobin due to nitrate/nitrite reduction through continuous dehydration and microbial activity until the product reaches its final stage may be the cause (Arnau et al., 2007; Salazar et al., 2015). However, since the salt used in this study consisted of purified NaCl with a purity of 99% or more, the effect of raw meat would have been greater than the effect of nitrate or nitrite. Ramírez et al. (2007) reported similar to our yellowness results, and the authors reported that the yellowness of a dry-cured loin made from a crossbreed of Iberian and Duroc was 5.1 to 6.3. On the other hand, Pateiro et al. (2014) reported that dry-cured loins made with Celta decreased with the processing stage, and the authors mentioned that there was a positive correlation with moisture loss. Also, yellowness is related to the fat content in meat, and Li et al. (2013) reported that yellowness and fat content had a positive correlation.

3.3. Texture profile analysis

The textural characteristics were analyzed according to the pig breed and processing stage (Table 3). In hardness, the significant difference between pig breeds was in raw meat stage and day 30 of drying-ripening ($p<0.05$), and Berkshire was higher than LYD. There was a significant difference depending on the processing stage ($p<0.05$). The hardness value of Berkshire decreased from 7.17 N in the raw meat stage to 2.69 N on the day 15 of drying-ripening and increased to 5.06 N on the day 30 of drying-ripening again. The LYD was similar result to that of Berkshire. The cohesiveness was not significantly different depending on the pig breed ($p>0.05$), but there was a significant difference depending on the processing stage ($p<0.05$). Also, it gradually increased as the processing stage progressed, and it tended to be maintained from day 15 of dry-ripening. The springiness showed a significant difference based on the processing stage ($p<0.05$), and on the contrary, the cohesiveness showed a tendency to decrease with the processing stage. The significant difference between the pig breeds was only in the cured meat, and it was seen that Berkshire was higher than LYD ($p<0.05$). There was no significant difference in chewiness between pig breeds ($p>0.05$), but there was a significant difference in processing stage ($p<0.05$). It decreased from the raw meat stage until day 15 of drying-ripening, but on the contrary, it increased again on day 30 of drying-ripening. In summary, there was no difference according to the pig breed, but there was a change in textural characteristics according to the processing stage. The textural component of dry cured meat is final result of the physical part expressed by various factors (oxidation, lipolysis, proteolysis, etc.) in quality characteristics, and it could be affected by consumer preference (Ruiz-Ramírez et al, 2005).

Based on this study results, day 30 drying-ripening of Berkshire has relatively low protein deterioration and its moisture content is high compared to those of LYD. Thus, it would have been little empty space inside of muscle by loss of moisture. For this reason, dry-cured loin of Berkshire could be a higher hardness than those of LYD on day 30 drying-ripening. The result of texture properties was very similar to the changes over the processing period of *m. semimembranosus* and *m. biceps femoris* as reported by Harkouss et al. (2015). The discussion of these authors is not sufficient to understand our results, but the trend in the results of the hardness was the same. This trend could be presumed by salting, water evaporation, and contraction. The salting could be led to internally deterioration of the loin, which can lead to loosen tissue. Also, during the initial drying-ripening, the pore will be formed in the place where moisture has evaporated, and the hardness will continue to decrease. However, as the drying-ripening continues, the loin is contracted, and the pores disappear, and the hardness will increase again. Also, Ruiz-Ramírez et al. (2005) found that moisture and water activity had a positive correlation with cohesiveness, and hardness and chewiness had a negative correlation. In view of this, the change in our textural properties is also closely related to moisture, and as the moisture evaporates over the processing stage, the pork loin partially contracts. Thus, the use of dry matter such as proteins could be increased during analysis resulting in higher hardness. In addition, high hardness requires a lot of strength in TPA analysis, and since this requires high strength in structural destruction, cohesiveness can be perceived to be rather low (Ramírez and Cava, 2005; Serra et al., 2005).

3.4. Lipid oxidation and sulfhydryl group

The result for lipid oxidation and sulfhydryl group are presented in Fig. 1 and Fig. 2, respectively. There was no significant difference in TBARS depending on the pig breed, but it gradually increased as the processing stage progressed ($p<0.05$). On the other hand, sulfhydryl groups were significantly higher in Berkshire from the beginning to day 30 of drying-ripening, and it decreased continuously from the beginning based on the processing stage ($p<0.05$). From our results, the moisture content of Berkshire was higher than those of LYD, which would be closely related to the reduction of sulfhydryl. Traore et al. (2012) reported a relationship between protein oxidation and drip loss for longissimus muscle, and the authors were found that there was a very high correlation between drip loss and protein oxidation. In addition, the high moisture content is thought to have a positive effect on the product yield and textural characteristics. TBARS is an important indicator for lipid oxidation, and which increase in lipid oxidation during processing is directly linked to the formation of free fatty acids and volatile compounds that affect the flavor (Jin et al., 2010). TBARS found in this study are in accordance with Ventanas et al. (2005). There was no statistical difference, but numerically, Berkshire had a high TBARS value, and which would have affected our fatty acid results (Table 4).

3.5. Free amino acids and fatty acid compositions

The contents of free amino acids and fatty acids are shown in Table 4. There was no difference in the free amino acid content at the initial stage ($p>0.05$), however, the free amino acids content for Berkshire was significantly higher from day 15 of drying-ripening to day 30 of drying-ripening ($p<0.05$). In addition, both of pig breeds were significantly increased until day 30 of drying-ripening ($p<0.05$). In the initial fatty acid content, there was no significant difference in PUFA between pig breeds ($p>0.05$). On the other hand, Berkshire was significantly higher in SFA, UFA, and MUFA ($p<0.05$). In addition, all fatty acid parameters significantly increased based on processing stage ($p<0.05$). Free amino acids and fatty acids are the final breakdown products of proteins and lipids and are the most important factors for taste and flavor in meat products (Martin et al., 1999; Ramalingam et al., 2019). In this regard, various attempts are still being made to measure and study their compositional forms in order to understand the relationships with sensory characteristics in detail. As a result, Berkshire showed a higher content of free amino acids and fatty acids than those of LYD, and this trend was maintained until the end of the processing. Abellán et al. (2018) reported similar results for the free amino acid content of dry-cured loin using refrigerated or frozen raw meat prepared for 50 days, and also, Martin et al. (2008) showed that the fatty acid content of dry cured loin prepared from pigs fed conjugated linoleic acid was similar to our results. The content of free fatty acids increases with the production stage because the reduction of neutral and polar lipids leads to the release of free fatty acids (Martin et al., 2008). The cause of this phenomenon may be enzyme activity and fat breakdown by oxidation. Muriel et al. (2007) investigated the changes in neutral and polar lipids in raw meat and dry-cured loin and reported that they decreased by 81% and 32%, respectively, compared to raw meat. In addition, the authors suggested that if oxidation is the cause of the decrease in neutral or polar lipids, SFA would be more prominent in PUFA than MUFA. It has been reported by many studies that the content of free amino acids increases as the dry ripening period increases in the manufacture of dry cured meat products (Abellán et al., 2018; Armenteros et al., 2012). These are cathepsins, an enzyme degrading in meat, dipeptidylpeptidases, and aminopeptidases. Toldrá et al., (1993) investigated the enzyme activity in dry-cured ham in relation to cathepsins and stated that cathepsins B, H, and L were active until the end of the product processing, but that the activity of cathepsin D was only a few months in the initial period. In our experiment, protein and lipid oxidation of Berkshire were lower than those of LYD (Fig. 1). Therefore, it is not appropriate to interpret that Berkshire had a higher free amino acids and fatty acids due to oxidation. Rather, as mentioned above, the assumption that the enzyme showed higher activity than LYD due to a higher moisture and pH would be more appropriate. In addition, there were no studies on enzyme activity in Berkshire and LYD, but studies mentioning that the genetic line of pigs may be strongly related to enzyme activity (Monin et al., 2003; Cava et al., 2004).

Conclusion

The present study compared the physicochemical properties of dry-cured loin manufactured with Berkshire and LYD. Depending on the manufacturing stage, dry-cured loin of Berkshire had higher moisture and pH compared to those of LYD. Because of that, there were higher content of fatty acid and amino acid than final product of LYD. Moreover, Berkshire showed a high lightness and redness, and it could be advantageous in consumer preference. Therefore, a study on the sensory characteristics of dry-cured loin manufactured with Berkshire should be carried out in the further study.

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Conflict of Interest

The authors declare no potential conflicts of interest.

Ethics Approval

This article does not require IRB/IACUC approval because there are no human and animal participants.

Author Contribution

Conceptualization: Yang HS, Seo JK. Data curation: Seo JK, Ko JH. Formal analysis: Seo JK, Ko JH, Park JY, Eom JU. Methodology: Seo JK, Yang HS. Software: Seo JK, Park JY. Validation: Seo JK, Eom JU. Writing -original draft: Seo JK. Writing -review & editing: Seo JK, Ko JH, Park JY, Eom JU, Yang HS.

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Figure legends

Fig. 1. The TBARS of dry-cured loin in different pig breeds and processing stage. Capital letter ($^{A-C}$) indicate significantly ($p<0.05$) differences between processing stage.

Fig. 2. The sulfhydryl of dry-cured loin in different pig breeds and processing stage. Capital letter ($^{A-C}$) indicate significantly ($p<0.05$) differences between processing stage. Small letter ($^{a-b}$) indicate significantly ($p<0.05$) differences between pig breeds.

Table 1

Effect of pig breed and processing stage on moisture content and pH of dry-cured loin.

Parameters	Pig breeds	Stage				SEM
		RM	CM	DR15	DR30	
Moisture (%)	Berkshire	73.11^{A}	73.22^{A}	65.28^{Ba}	59.60^{Ca}	0.49
	LYD	73.49^{A}	72.05^{A}	62.83^{Bb}	53.29^{Cb}	0.54
	SEM	0.45	0.44	0.49	0.68	
pH	Berkshire	5.75^{B}	5.87^{B}	5.99^{Ba}	6.17^{Aa}	0.09
	LYD	5.65^{B}	5.73^{B}	5.84^{ABb}	5.94^{Ab}	0.07
	SEM	0.08	0.10	0.07	0.07	

LYD: Landrace × Yorkshire × Duroc.

SEM: Standard error of the means.

$^{A\text{-}C}$Means with upper letter in same animal significantly differ.

$^{a\text{-}b}$Means with small letter in same stage significantly differ.

Stage: RM, raw meat; CM, cured meat; DR15, day 15 of drying-ripening; DR30, day 30 of drying-ripening.

Table 2

Effect of pig breed and processing stage on color of dry-cured loin.

Parameters	Pig breeds	Stage				SEM
		RM	CM	DR15	DR30	
Lightness	Berkshire	51.20^{A}	47.36^{Ba}	45.50^{Ba}	44.88^{Ba}	0.66
	LYD	52.43^{A}	45.04^{Bb}	43.03^{Bb}	40.30^{Cb}	0.27
	SEM	0.70	0.19	0.17	0.81	
Redness	Berkshire	5.81^{Ca}	5.69^{C}	6.99^{Ba}	8.38^{Aa}	0.70
	LYD	5.20^{Cb}	5.44^{C}	6.03^{Bb}	6.24^{Ab}	0.35
	SEM	0.30	0.31	0.19	0.31	
Yellowness	Berkshire	5.14^{Ba}	4.86^{Ba}	5.23^{Ba}	6.59^{Aa}	0.51
	LYD	4.21^{Bb}	4.15^{Bb}	4.72^{Ab}	5.82^{Ab}	0.28
	SEM	0.40	0.31	0.34	0.51	
Chroma	Berkshire	7.76^{Ba}	8.00^{Ba}	8.61^{Aa}	9.61^{Aa}	0.52
	LYD	6.72^{Bb}	6.88^{Bb}	7.88^{Bb}	8.39^{Ab}	0.73
	SEM	0.45	0.34	1.24	0.47	
Hue angle	Berkshire	41.55^{Ba}	38.17^{Ba}	37.49^{B}	43.22^{A}	1.52
	LYD	38.19^{Bb}	36.92^{Bb}	37.32^{B}	43.91^{A}	0.94
	SEM	1.06	1.51	0.92	1.43	

LYD: Landrace × Yorkshire × Duroc.

SEM: Standard error of the means

$^{A\text{-}C}$Means with upper letter in same animal significantly differ.

$^{a\text{-}b}$Means with small letter in same stage significantly differ.

Stage: RM, raw meat; CM, cured meat; DR15, day 15 of drying-ripening; DR30, day 30 of drying-ripening.

Table 3

Effect of pig breed and processing stage on texture properties of dry-cured loin.

Parameters	Pig breeds	Stage				SEM
		RM	CM	DR15	DR30	
Hardness (N)	Berkshire	7.17^{Aa}	4.33^{B}	2.69^{C}	5.06^{ABa}	0.66
	LYD	5.66^{Ab}	4.18^{AB}	2.29^{B}	4.47^{Ab}	0.60
	SEM	1.09	0.54	0.26	0.61	
Cohesiveness	Berkshire	0.38^{C}	0.47^{B}	0.55^{A}	0.51^{ABb}	0.01
	LYD	0.39^{B}	0.48^{AB}	0.56^{A}	0.54^{Aa}	0.03
	SEM	0.04	0.01	0.01	0.01	
Springiness (mm)	Berkshire	0.92^{A}	0.91^{Aa}	0.84^{B}	0.82^{B}	0.02
	LYD	0.95^{A}	0.81^{Bb}	0.81^{B}	0.84^{B}	0.02
	SEM	0.01	0.03	0.02	0.01	
Chewiness (Nm)	Berkshire	2.45^{A}	1.85^{AB}	1.24^{B}	2.11^{A}	0.26
	LYD	2.81^{A}	1.62^{BC}	1.03^{C}	1.99^{AB}	0.25
	SEM	0.41	0.21	0.11	0.29	

LYD: Landrace × Yorkshire × Duroc.

SEM: Standard error of the means.

$^{A\text{-}C}$Means with upper letter in same animal significantly differ.

$^{a\text{-}b}$Means with small letter in same stage significantly differ.

Stage: RM, raw meat; CM, cured meat; DR15, day 15 of drying-ripening; DR30, day 30 of drying-ripening.

Table 4

Effect of pig breed and processing stage on free amino acid and fatty acid of dry- cured loin.

Parameters	Pig breeds	Stage				SEM
		RM	CM	DR15	DR30	
TFAA (mg/100g)	Berkshire	1956.98^{C}	2165.75^{C}	2465.154^{Ba}	2690.32^{Aa}	35.25
	LYD	1798.34^{B}	1965.56^{B}	2095.36^{ABb}	2137.40^{Ab}	32.88
	SEM	20.36	30.54	15.32	28.65	
SFA (mg/g)	Berkshire	9.51^{Ca}	9.54^{Ca}	13.06^{B}	17.09^{Aa}	0.77
	LYD	7.75^{Bb}	7.60^{Bb}	12.93^{AB}	15.92^{Ab}	0.59
	SEM	0.74	0.43	0.69	0.76	
UFA (mg/g)	Berkshire	15.89^{Ca}	15.86^{Ca}	22.84^{Ba}	27.73^{Aa}	0.42
	LYD	10.38^{Cb}	11.18^{Cb}	17.31^{Bb}	25.28^{Ab}	0.77
	SEM	0.39	0.59	0.06	0.35	
MUFA (mg/g)	Berkshire	12.19^{Ca}	11.57^{Ca}	16.94^{Ba}	21.92^{Aa}	0.74
	LYD	8.28^{Cb}	8.27^{Cb}	13.53^{Bb}	19.61^{Ab}	0.45
	SEM	0.08	0.32	0.55	0.45	
PUFA (mg/g)	Berkshire	3.70^{B}	4.30^{Ba}	5.90^{Aa}	5.81^{Aa}	0.79
	LYD	2.09^{B}	2.91^{Bb}	3.78^{Bb}	4.67^{Ab}	0.47
	SEM	0.36	0.35	0.73	0.29	

LYD: Landrace × Yorkshire × Duroc.

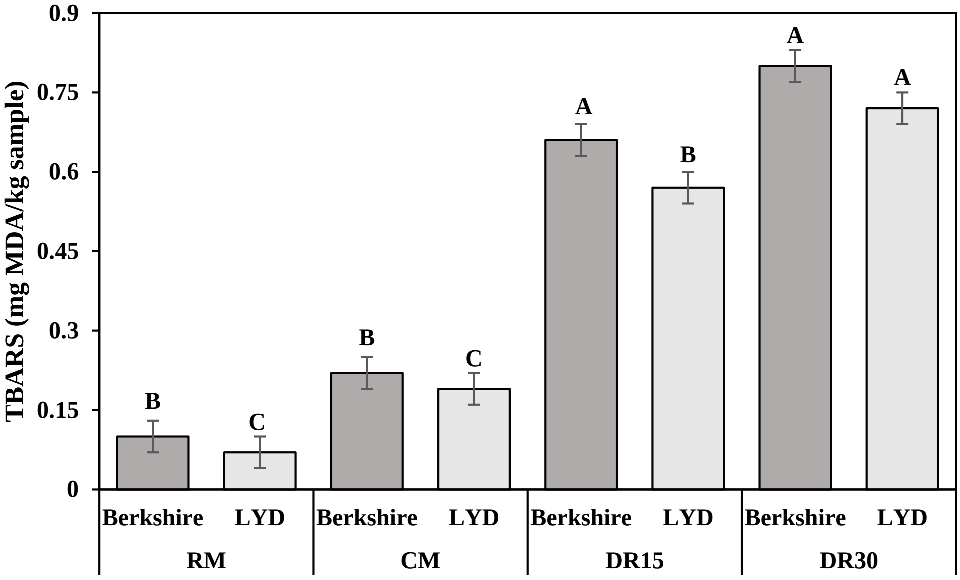
SEM: Standard error of the means.

$^{A\text{-}C}$Means with upper letter in same animal significantly differ.

$^{a\text{-}b}$Means with small letter in same stage significantly differ.

Stage: RM, raw meat; CM, cured meat; DR15, day 15 of drying-ripening; DR30, day 30 of drying-ripening.

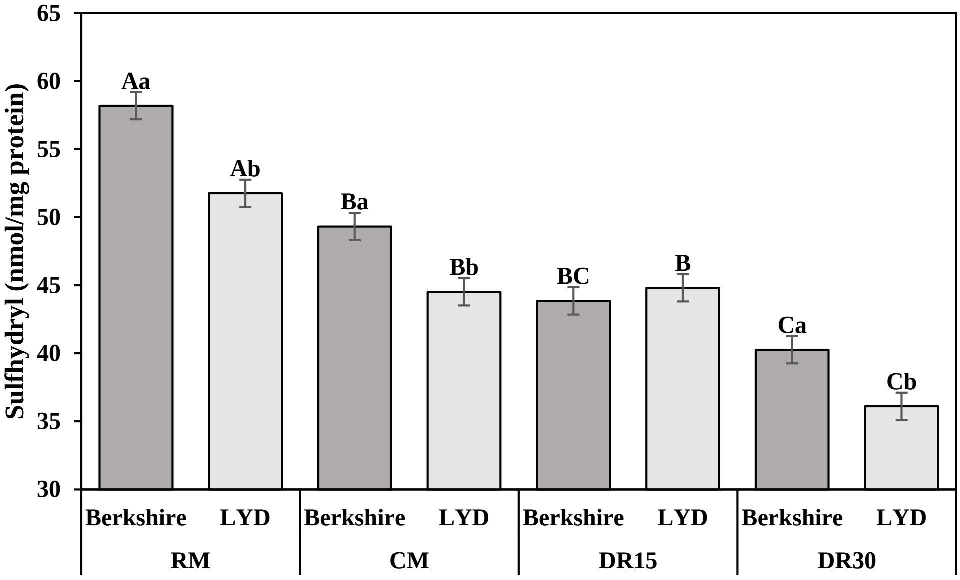
TFAA, total free amino acid; SFA, saturated fatty acid; UFA, unsaturated fatty acid, MUFA, monounsaturated fatty acid; PUFA, polyunsaturated fatty acid.



TBARS (mg MDA/kg sample)
0.9
0.75
0.6
0.45
0.3
0.15
0
B
C
B
C
A
B
A
A
Berkshire
LYD
Berkshire
LYD
Berkshire
LYD
Berkshire
LYD
RM
CM
DR15
DR30

565

566


Sulfhydryl (nmol/mg protein)
65
60
55
50
45
40
35
30
Aa
Ab
Ba
Bb
BC
B
Ca
Cb
Berkshire
LYD
Berkshire
LYD
Berkshire
LYD
Berkshire
LYD
RM
CM
DR15
DR30