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Comparison of physicochemical traits of dry-cured ham from purebred Berkshire and crossbred Landrace × Yorkshire × Duroc (LYD) pigs

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Abstract

This study was conducted to compare the physicochemical traits of dry-cured hams made from two different pig breeds: Berkshire and Landrace × Yorkshire × Duroc (LYD). Pigs were slaughtered at a live weight of approximately 110 kg and cooled at 0°C for 24 h in a chilling room. Then, the ham portion of the carcasses were cut and processed by dry-curing for physicochemical analyses. The dry-cured hams from Berkshire contain higher crude protein, fat, and ash level than those from LYD, whereas the hams from LYD had higher moisture contents than those from Berkshire($p < 0.05$). The pH values of the hams from Berkshire were lower than those from LYD ($p < 0.05$). The hams from Berkshire had lower L* and b* values than those from LYD ($p < 0.05$). Palmitoleic acid (C16:1), oleic acid (C18:1), elaidic acid (C18:1t), monounsaturated fatty acids, and ratio of n-6 and n-3 fatty acids (n-6/n-3) in the ham from Berkshire were higher than LYD ($p < 0.05$). Free amino acids such as aspartic acid, threonine, serine, asparagine, glutamic acid, and lysine in hams from Berkshire were higher than those from LYD ($p < 0.05$). The microbial population had no significant difference between Berkshire and LYD dry-cured ham. The cross sections of dry cured ham showed difference from different breeds using scanning electron microscope and indicates some differences in texture. Considering the meat quality parameters of ham, hams from Berkshire could provide variety of ham for consumer who are seeking various different qualities and stories.

Keywords: Berkshire, LYD, Dry-cured ham, Physicochemical traits

Introduction

Dry-cured ham is a complex product, since the influence of the pigs used as raw material (genetic type, feed, rearing system, etc.) as well as the variety of processing technologies (conditions for curing, ripening, etc.) contribute to quality of ham [1]. Korea has good circumstances for producing dry-cured ham because the ham resources are abundant and inexpensive [2]. However, few studies have been made on the physicochemical traits of Korean traditional dry-cured ham. Different genetic groups of pigs have been used to obtain fresh hams with ideal quality traits and, in particular, its crossbreds fulfill meat quality criteria for dry-ham processing [3]. Individual species in pigs have their own different traits. Berkshire pigs have black glossy hair color, short necks, and erect ears, whereas LYD pigs have white coats [4]. Berkshire breed had tender texture and greater water-holding capacity, as well as darker fresh meat color compared with other

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breeds [5, 6]. Thus, Berkshire breed is known for good meat quality, especially appropriate for cured products [7]. On the other hand, Duroc breed has not only an excellent growth rate and a higher fat content compared to the Landrace and Yorkshire [8], but also used as a terminal sire to enhance intramuscular fat and growth rate of the three-way crossbreds [9]. Landrace pigs have a thin subcutaneous fat layer, large hams and high muscularity in the carcass [10]. Crossing in pig production is aimed to increase the total efficiency and also to enhance the quantity and quality of the meat [11]. Traditionally, common crossbreeding used in Europe for the production of high quality dry-cured ham is Yorkshire × Berkshire × Duroc (YBD). The majority of pig production in Korea is three-way crosses with LYD and these crossbreds have an excellent growth rate, higher yields and bigger litter size than other crossbreds [10]. Although LYD pigs and are mainly used for commercial pork production, differences in meat quality traits between Berkshire and LYD pigs remain poorly characterized [9]. It is worth to investigate the meat quality of various types of genetics to fulfill a diversity of consumer's opinions. Although previous study has been described on comparison between the crosses and meat quality [10], a little data is available on the quality comparison of dry-cured hams between purebred Berkshire and LYD. Therefore, the aim of this research was to compare the physicochemical traits of dry-cured hams made from Berkshire and LYD pigs.

Materials and Methods

Animals, sample collection, and processing of the hams

Twenty gilts (n=10 for each breed), 200 days old, were evaluated from the LYD and Berkshire pigs. The pigs were born and raised in different pens at a local swine farm (Namwon, Korea). Animals were fed the same commercial feed including the fattening period from weaning weight (30 kg) to slaughter weight (~110 kg). These pigs were housed in partially slotted and concrete floor pens having a pen size of 5 m × 4.8 m. Pens were equipped with a self-feeder and nipple waterer to allow *ad libitum* access to feed and water. Animals were fed a commercial feed *"ad libitum"* with a composition of 16.5% protein, 5.2% fat and 3,400 kcal/kg metabolic energy. Pigs from each crossbred were randomly selected from 110–120 kg range of marketing weight, slaughtered, and cooled at 0℃ for 24 h in a chilling room. The carcasses were deboned and the left hind legs were used. After they were thoroughly rubbed with a mixture of 50 g domestic sun-dried salt per kg of pork hind leg, they were stored in a salting chamber at a relative humidity (RH) of 75 ± 5% and a temperature of 3 ± 1℃ for 30 days. After salting, the samples were soaked in cold water and washed. Subsequently, hind legs were dried for 90 days at 20 ± 3℃ and at 80%–100% RH. Finally, they were ripened for 20 additional months at 20 ± 2℃ and at 65%–75% RH. After the ripening stage, the muscles were sliced (10 cm thickness) using a slicer (Fujee Co., Seoul, Korea). Before analysis, the fat was manually removed from the ham slices using a knife. All determinations were carried out on mainly *biceps femoris* muscles, in triplicate.

Proximate composition and pH

The proximate composition was obtained with a slightly modified method of [12]. Briefly, the moisture content was obtained by drying each sample (3 g) placed in an aluminum dish at 104°C for 15 h. The crude protein contents were measured by the Kjeldahl method (VAPO45, Gerhardt Ltd., Idar-Oberstein, Germany). The crude fat contents were measured using the Soxhlet extraction system (TT 12/A, Gerhardt Ltd., Idar-Oberstein, Germany). The crude ash content was measured by igniting 2 g of each sample in a furnace at 600°C overnight. The pH of samples was measured in triplicate using a digital pH meter (Orion 2 Star, Thermo scientific, USA). A slurry was prepared by blending a 10 g dry-cured ham sample with 90 mL distilled water for 60 s in a homogenizer (Polytron PT 10-35 GT, Kinematica AG, Switzerland). The electrode was calibrated with pH 4.01 and 7.00 standard buffers equilibrated at 25°C for the measurements.

Meat color

The surface color value of the samples was measured using the CIE L*, a* and b* system using a Minolta chromameter (Model CR-410, Minolta Co. Ltd., Japan), with measurements standardized with respect to a white calibration plate (L* = 89.2, a* = 0.921, b* = 0.783) after 30 min blooming at room temperature. Color measurements always trying to avoid area with excess fat were taken and the value was recorded.

Fatty acid analysis

The fatty acids composition was determined by using a slightly modified method of [13]. For the separation of fatty acid methyl esters, one gram of sample from each treatment was mixed with 0.7 mL of 10N KOH and 6.3 mL of methanol, placed in a constant temperature water bath at 55℃ and then heated. After warming for 1 hour and 30 minutes, it was vigorously shaken once every 30 minutes. After cooling for 1–2 minutes in cold water, 0.58 mL of (24N) H_2SO_4 was added, and the mixture was incubated at 55℃ for 1 hour and 30 minutes while heating, it was vigorously shaken again once every 30 minutes. After heating, 3 mL of hexane was added to the prepared cold water, and the mixture was centrifuged (HANIL, Combi-514R, KOR) at 3,000 rpm for 5 minutes. After immersing in a vial using a Pasteur pipette, fatty acid analysis was performed using the Gas Chromatograph-Flame Ionization Detector (Agilent, 7890 series, USA) under the following conditions. Injector was split mode with split ratio of 25:1, temperature was 250℃, detector was Flame Ionization Detector (FID) and tem-

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perature was 250℃. High purity air, high purity H_2 and high purity He were used as the carrier gas. The flow rate was 40 mL/min for H_2 and 400 mL/min for air. HP-88 column (60 m × 250 μm × 0.2 mm) was used for the analysis. Fatty acids were expressed as a percentage of total fatty acids identified, saturated fatty acid (SFA), mono-unsaturated fatty acid (MUFA) and poly-unsaturated fatty acid (PUFA). PUFA/SFA and n-6/n-3 ratios were calculated.

Free amino acid analysis

The composition of free amino acids was determined by the modified method of [14]. Visible external fat was removed and meat sample (5 g) was mixed with 20 mL of 2% TCA solution. The mixture was homogenized at 13,500 rpm/min for 1 min. The homogenate was then centrifuged at 17,000 × g for 15 min and filtered through 0.45 μm membrane filter. The filtrate was derivatized by the method of Waters AccQ-Tag™ (Millipore Co-Operative, Milford, MA, USA) and 5 μL was injected into an HPLC (Waters HPLC column, Novapak C18. 60 Angstrom, 4 × 3.9 × 150 mm). Separation was by using buffers: A (sodium acetate, pH 6.4, 5,000 ppm EDTA, triethylamine (1:2,000) and 6%, v/v, acetonitrile) and B (60%, v/v, acetonitrile and 5,000 ppm EDTA). A 1525 HPLC with a binary gradient delivery, a 717 auto sampler and an injector, 1500 column heater and 2487 dual wavelength UV detector were the equipment used in the analysis by Breeze Software Z (Waters, Milford, MA, USA). Accuracy and repeatability of this analysis is ensured by the inclusion of a control sample of known amino acid composition with the samples prior to hydrolysis.

Scanning electron microscopy (SEM)

For the SEM analysis, five additional specimens from each sample and treatment (Berkshire and LYD pigs) were obtained. Specimens were accurately carved with a scalpel into parallelepipeds of 2 × 2 × 1 mm^3 (length × width × height) and then fixed (primary fixation with Karnovsky's fixative and post fixation with 2% osmium tetroxide and 0.1 M Sodium cacodylate buffer). Afterwards, the specimens were dehydrated in an increasing ethanol series, ultra-dehydrated by the critical point method with CO_2 and coated with white gold in an EM ACE200 equipment (10 nm, 30 mA, 2 min). Examinations were carried out with a scanning electron microscope SIGMA at 2 kV and at working distance of 3.5 mm (Carl Zeiss, Oberkochen, Germany).

Statistical methods

An analysis of variance (ANOVA) was performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package [15]. The *t*-test ($p < 0.05$) was used to determine differences among the treatment means. Mean values and standard deviations were reported.

Results and Discussion

Physicochemical characteristics

Comparison of proximate composition of dry-cured ham made from Berkshire and LYD is shown in Table 1. Moisture content is considered as an indicator of the degree of drying as well as the shelf-stability of dry-cured ham [2]. Fat content in cured hams is considered a crucial trait in contribution to the appearance, texture and sensory traits [16]. While the crude protein, fat and ash contents of dry-cured ham were higher in Berkshire than in LYD, moisture contents were only lower in Berkshire($p < 0.05$). The genetic background significantly affects the proximate composition of dry-cured hams [17]. The higher the fat content, the greater the acceptability of dry-cured hams [16]. The pH values of the hams were lower in Berkshire than in LYD ($p < 0.05$). Additionally, the higher pH of LYD hams ay decreases drip loss and increase ADP concentrations [4]. There were no significant differences in the pH value were found between Berkshire and LYD, as in a previsous study [2].

Regarding color measurement, Berkshire ham samples showed a significantly lower L* and b* values than LYD ($p < 0.05$). Lightness is related to the thin aqueous layer on the muscle's surface [18]. These results suggest that lightness in muscles depends on the moisture content and water movement (dehydration) towards the surface [19]. Accordingly, it is possible that the lower moisture content in Berkshire hams could be the factor for the lower lightness values of the hams. Similar findings were reported that the Berkshire pigs showed a lower L* and b* values than LYD [4, 5]. This is may be explained by a higher proportion of type I muscle fibers than other breeds [6]. The redness is one of the most crucial color parameters for the dry-cured ham, whereas the high lightness

Table 1. Proximate composition (%), pH, and meat color of dry-cured ham from Berkshire and LYD pigs

	Breed	
	Berkshire	LYD
Moisture	39.33 ± 0.62[b]	54.83 ± 0.96[a]
Crude protein	39.96 ± 0.88[a]	35.04 ± 0.95[b]
Crude fat	14.40 ± 3.21[a]	7.03 ± 0.91[b]
Crude ash	7.43 ± 0.29[a]	6.09 ± 0.03[b]
pH	6.00 ± 0.01[b]	6.09 ± 0.01[a]
CIE L*	32.37 ± 1.90[b]	35.48 ± 0.37[a]
CIE a*	15.29 ± 1.36	16.55 ± 1.09
CIE b*	7.98 ± 0.12[b]	8.71 ± 0.12[a]

All values are mean ± standard deviation (n=10).

[a,b]Means with different letters within a same row differ significantly, ($p < 0.05$).

LYD, Landrace × Yorkshire × Duroc.

level is undesirable [2]. The difference in the color parameters of dry-cured hams in this study is probably attributed due to differences in the muscle composition, such as moisture, fat and pigment contents, and oxidative status of the hams between the breeds [2].

Fatty acid composition

Breed or genotype plays a decisive role in fatty acid composition of the meat [20]. Fatty acid compositions of dry cured ham from Berkshire and LYD are shown in Table 2. The major fatty acids in the hams were oleic (C18:1), palmitic (C16:0), linoleic (C18:2), and stearic (C18:0) acids, which are listed from the most prevalent to the least. This is in agreement with results previously reported [2]. These four fatty acids accounted for over 88% of the total fatty acids in the fat. The difference by breeding effects was shown in some fatty acids. In particular, Berkshire ham samples had higher percentage of palmitoleic (C16:1), oleic (C18:1), Elaidic acid (C18:1t), MUFA, and ratio of n-6 and n-3 fatty acids (n-6/n-3) than LYD ($p < 0.05$). Similar results have been reported [2]. It also suggested that Berkshire pigs showed greater oleic acid and MUFA contents than LYD [4]. Stearic acid (C18:0), known as a neutral fatty acid [21], were much lower in the Berkshire ham samples than LYD ($p < 0.05$). The increased fat content could increase oleic acid and the level of oleic acid positively correlates to the oiliness and brightness of dry-cured ham [22]. On the contrary, high proportions of PUFA have also been reported to have a negative effect on the oiliness and brightness of dry-cured ham [22]. Numerous studies have demonstrated that ratio of n-6 and n-3 fatty acids is correlated with a risk of coronary heart disease and a balanced diet of n-6 and n-3 fatty acids is of importance for human health [23]. Remarkably, variations in fatty acid composition between Berkshire and LYD hams may be caused by a different fat content and potential for endogenous synthesis of fatty acids [24]. In our study, we found a great variation in the proportion of fatty acids among the breeds and Berkshire hams showed higher MUFA contents, potentially leading to positive effects on heart disease risk.

Free amino acid composition

The profile of free amino acids of a food is known to be related to the development of a particular taste, flavor or aroma like saltiness, acid taste, bitter taste, etc. [25]. The free amino acid composition of dry-cured ham from Berkshire and LYD are given in Table 3. The redominant free amino acid for the present study was glutamic acid known for umami taste. Aspartic acid, threonine, serine, asparagine, glutamic acid, and lysine in hams were much higher in Berkshire with the respect to LYD ($p < 0.05$) [4]. Amino acid accumulations in meats were associated with decreased WHC (water holding capacity) [26]. These analyses show that hams from Berkshire are highly enriched in most essential amino acids, suggesting that Berkshire hams are of great importance to eating quality and have higher nutritional values than LYD ones.

Table 2. Fatty acid composition (%) of dry-cured ham from Berkshire and LYD

	Breed	
	Berkshire	LYD
C10:0	0.12 ± 0.09	0.10 ± 0.07
C12:0	0.10 ± 0.03	0.09 ± 0.03
C14:0	1.39 ± 0.33	1.18 ± 0.23
C16:0	23.24 ± 2.73	21.36 ± 2.39
C16:1	4.05 ± 0.03[a]	2.27 ± 0.01[b]
C18:0	10.17 ± 0.09[b]	10.39 ± 0.06[a]
C18:1t	0.31 ± 0.00[a]	0.15 ± 0.02[b]
C18:1	44.11 ± 0.17[a]	43.80 ± 0.04[b]
C18:2	11.31 ± 1.43	12.51 ± 1.78
C18:3	0.66 ± 0.63	1.10 ± 0.69
C20:2	0.37 ± 0.39	0.50 ± 0.31
C20:3	0.26 ± 0.37	0.40 ± 0.31
C20:4	1.55 ± 1.32	2.66 ± 1.43
C24:1	0.29 ± 0.18	0.41 ± 0.17
SFA	35.03 ± 2.23	33.11 ± 3.02
UFA	62.89 ± 1.33	63.81 ± 1.51
MUFA	48.76 ± 0.19[a]	46.64 ± 0.03[b]
PUFA	14.13 ± 4.03	17.17 ± 3.75
UFA/SFA	1.80 ± 0.19	1.93 ± 0.18
n-6/n-3	17.27 ± 0.11[a]	11.31 ± 0.19[b]

All values are mean ± standard deviation (n=10)

[a,b]Meanswith different letters within a same row differ significantly, ($p < 0.05$).

LYD, Landrace × Yorkshire × Duroc; SFA, saturated fatty acids; UFA, unsaturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids.

Scanning electron microscopy (SEM)

Both hams showed the shrinkage of muscle fiber due to the curing with salt and this phenomenon was stronger in Berkshire hams than LYD (Fig. 1). As the shrinkage of muscle fiber is related to the loss of moisture content as well as the disruption of matrix [27], the significant differences in moisture content and meat color might be reasonable in the present study (Table 1). The significant difference in morphology between the dry-cured hams from two breeds is probably due to the type of muscle fiber, which is varied with different breed [28]. Their morphological difference by moisture loss might change texture profile of the products [29].

Conclusion

Breed affects and alters meat quality of the dry-cured ham to some

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Table 3. Free amino acid composition (mg/100 g) of dry-cured ham from Berkshire and LYD

	Breed	
	Berkshire	LYD[1]
Taurine (sour)	35.78 ± 5.21	36.51 ± 4.21
Aspartic acid	192.69 ± 15.47[a]	152.56 ± 13.43[b]
Threonine	190.54 ± 15.36[a]	158.65 ± 13.70[b]
Serine (very sweet)	170.40 ± 6.19[a]	151.17 ± 2.93[b]
Asparagine (good)	6.70 ± 1.56[a]	1.85 ± 1.08[b]
Glutamic acid (umami)	425.14 ± 33.48[a]	343.82 ± 32.64[b]
Glycine (very sweet)	353.81 ± 42.11	324.70 ± 35.38
Alanine (sweet)	364.07 ± 45.96	308.57 ± 77.05
Valine (bitter)	206.42 ± 25.84	186.32 ± 39.29
Methionine	98.74 ± 15.48	85.39 ± 14.03
Isoleucine (very bitter)	136.2 ± 16.23	122.57 ± 10.86
Leucine	300.09 ± 37.37	273.61 ± 29.40
Tyrosine	110.02 ± 14.48	99.09 ± 22.79
Phenylalanine (bitter)	137.48 ± 12.92	127.41 ± 19.68
Histamine (bitter)	79.91 ± 12.64	86.41 ± 13.47
Tryptophan	16.58 ± 2.56	17.04 ± 2.61
Lysine (sweet)	337.41 ± 55.02[a]	162.97 ± 94.34[b]
Ammonia	278.93 ± 45.83	257.13 ± 72.70
Arginine (bitter)	49.41 ± 19.60	41.57 ± 15.30

All values are mean ± standard deviation (n=10).

[a,b]Meanswith different letters within a same row differ significantly, ($p < 0.05$).

LYD, Landrace × Yorkshire × Duroc.

extent. It is conceivable that in overall Berkshire hams have better meat quality than LYD ones. In addition, the processed ham from Berkshire pigs contained significantly higher levels of some fatty acids and free amino acids, and showed different textural appearance. Therefore, the present study confirms that the use of Berkshire for ham manufacturing can be beneficial for consumers who are seeking diverse meat products for their diet.

Competing interests

No potential conflict of interest relevant to this article was reported.

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Not applicable.

Availability of data and materials

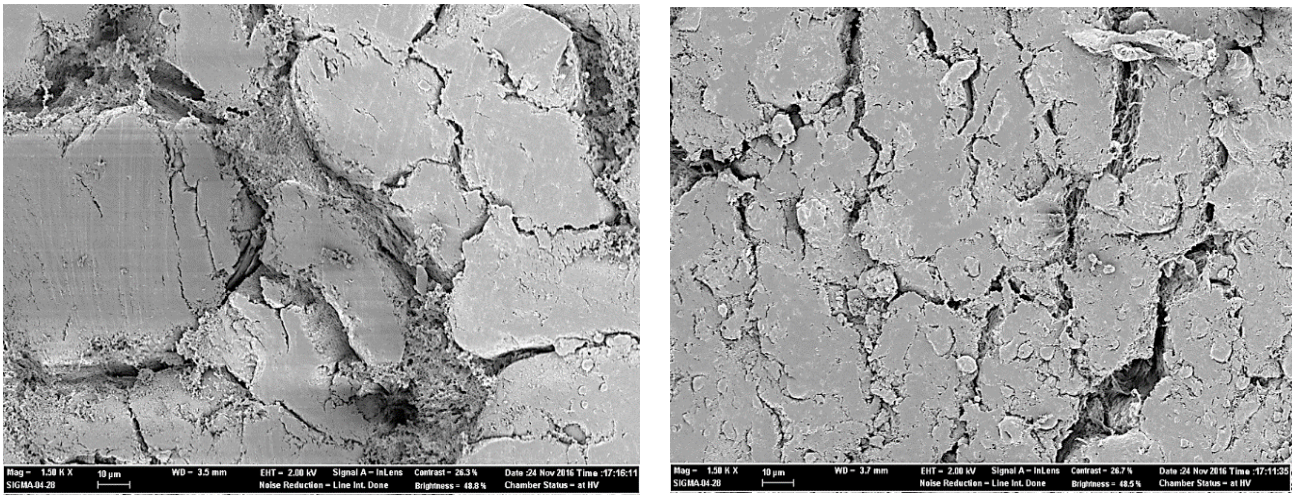
Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions

Conceptualization: Nam KC.
Methodology: Yim DG, Ali MM.
Validation: Jung JH.
Investigation: Yim DG, Ali MM.
Writing - original draft: Yim DG.
Writing - review & editing: Ali MM, Nam KC.

Ethics approval and consent to participate

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



(A) (B)

Fig. 1. Cross section dry-cured ham from (A) Berkshire and (B) Landrace ×Yorkshire× Duroc (LYD) observed by scanning electron microscopy.

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