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ARTICLE

Quality Comparison of Pork Loin and Belly from Three-way Crossbred Pigs during Postmortem Storage

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Abstract

This study was performed to determine the meat quality characteristics of pork loin and belly from 3 different three-way crossbred pigs: Yorkshire × Landrace × Duroc (YLD), Yorkshire × Chester White × Yorkshire (YCY), and Yorkshire × Berkshire × Duroc (YBD). Each of the twenty crossed pigs were randomly selected with their live weights at the range of 110-120 kg. After being slaughtered and cooled at 0°C for 24 h in a chilling room, the parts of loin and belly on the left side of the cooled carcasses were cut and prepared for analysis. The intramuscular fat contents of the loins from YLD were higher than those of the other crossbreds (p<0.05), and the YCY bellies had the highest moisture contents (p<0.05). Water holding capacity (WHC) of the loins from YCY were higher than the other crossbreds (p<0.05). Shear force values of the YBD loins were higher than the others (p<0.05). The TBARS values of YCY loins were significantly lower than the others at 0 d, but the difference disappeared after 14 d of storage. Sensory scores of YLD were ranked higher than the YCY or YBD in both the loins and bellies (p<0.05). The relatively high sensory values of YLD crossbred pork could be explained by the better WHC, the low shear forces, and the higher fat contents. The results indicated that the meat qualities could be altered by three-way crossbreeding.

Key words: three-way crossbred, pork loin, pork belly, meat quality, sensory

Introduction

Pork quality could be affected by the factors e.g., breed, animal nutrition, and pre-and post-slaughter managements. However, breed could be attributed as to the most significant single factor influencing the meat quality traits (Josell *et al*., 2003). Crossbreeding is extensively used in pig production to increase the total efficiency of pig production and also to improve the quantity and quality of the meat (Bennet *et al*., 1983). Crossbred advantage is maximized in an individual born from a three-way cross and is twice as large as in the progeny of a backcross (Langlois and Minvielle, 1989).

Presently, the majority of finishing pig production in Korea is based on the crossbreds and generally is three-way crosses with Landrace and Yorkshire × Duroc. These crossbred pigs retain the traits of an excellent growth rate, higher yields and bigger litter size than other crossbreds selected and tested (Hong *et al*., 2001; Jin *et al*., 2005). For this reason, approximately 60% of the 15.3 million pigs annually slaughtered are composed of three-way crossbreds in pork industry (Kim *et al.,* 2006).

A few studies investigated the crossbreeding effect of genetic factors on meat quality (Ruusunen *et al*., 2012; Suzuki *et al*., 2003). Previous research on comparison between the breed and meat quality has only assessed in the parts of loins. Kim *et al.* (2006) mentioned that LYD pigs had lower shear force values and higher WHC among breeds.

It is worth to investigate the meat quality of different types of crossbreeds to fulfill a diversity of consumers' opinions. In this respect, it is invaluable to study the effect of three-way crossbreeding on meat quality since the studies for the subject have little information. In recent years, pork bellies are the most demanding and popular cuts in most Korean meat consumers and consequently their retail prices are much higher than other cuts. There

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is little information on meat quality traits of three-way crossbreds in pork belly known for popular cuts. Also, few studies have examined the effect of three-way crossbreeding on composition of physicochemical traits, fatty acid and sensory traits. Therefore, the objective of this study was to compare the quality of pork loin and belly including fatty acid compositions and sensory traits from three-way crossbreds of Yorkshire × Landrace × Duroc (YLD), Yorkshire × Chester White × Yorkshire (YCY), and Yorkshire × Berkshire × Duroc (YBD).

Materials and Methods

Animals, Sample collection and preparation for analysis

A total of 60 gilts (female pig), 185-190 d old, were evaluated from three different crossbreeding schemes which included YLD, YCY, and YBD with 20 animals in each scheme. The pigs were born and raised at swine breeding farm, Breeding Pig Improvement Center (Nong-Hyup: Korea). Animals were fed the same commercial feed, raised under similar conditions and transported from the farm to the slaughterhouse. Twenty pigs from each crossbred were randomly selected from 110-120 kg range of marketing weight, slaughtered, and cooled at 0°C for 24 h in a chilling room. The parts of loins and bellies on the left side of the cooled carcasses were used to measure meat quality parameters. All samples were placed in vacuum bags and subsequently transported to the laboratory. And they were stored and frozen at -18°C in deep freezer until they were analyzed. All samples were used at the same location on the loins and bellies over the middle portion and excess fat and bone were removed from the muscles. Prior to analysis, the samples were thawed overnight at 4°C.

pH measurement

The pH of samples was determined with a pH electrode (Orion 2 Star, Thermo scientific, USA). The pH values of pork samples were measured by blending a 3 g sample with 27 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.

Moisture and total fat

The samples were trimmed of all external fat prior to analysis. Moisture content was obtained with a slightly modified method of AOAC (2000). The total moisture content of 3 g of samples placed in aluminum moisture dishes were determined from their pre-dry and dry weights (dried in an air oven at 104°C for 24 h) and expressed as the percentage of pre-dry weight and gram water per gram dry weight. The moisture content was determined in triplicate on each sample. Fats were extracted from 5 g of meat with chloroform/methanol (2:1), according to the method described by Folch *et al*. (1957).

Drip and cooking loss

Drip and cooking loss were analyzed by the method described by the procedure of Kang *et al*. (2011). Percentage drip loss was determined by dividing the weight loss during thawing by the frozen weight of each sample. For cooking loss, after the samples were thawed, they with a thickness of 2 cm were weighed and cooked in a electric grill (HD 6320, Philips Electronics, Netheland) until they reached a final internal temperature of 72±2°C. Percentage cooking loss was determined by dividing the weight loss during cooking by the pre-cooked weight.

Instrumental measurement of color

The surface color value of the pork belly samples were measured by 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 for each of three replicates, always trying to avoid area with excess fat were taken and the value was recorded.

Shear force measurement

Shear force values were analyzed by the method described by the procedure of Kang *et al*. (2011). The samples were prepared a cubic form (20×20×10 mm) and heated during 90 s in electrical grill (Nova EMG-533, 1,400W, Evergreen enterprise, Korea). Internal temperature of the samples during heating was 72±2°C and then cooled for 30 min at room temperature. Each sample was cut perpendicular to the longitudinal orientation of the muscle fiber with a Warner-Bratzler shear attachment on a texture analyzer (TA-XT2i, Stable Micro System Ltd., U.K.), and measured the maximum shear force (unit: kg). Test and pre-test speeds were set at 2.0 mm/s. Post-test speeds were set at 5.0 mm/s. Data were collected and analyzed from the shear force values to obtain for the maximum force required to shear through each sample.

Water Holding Capacity (WHC)

Water-holding capacity was determined in duplicate in fresh meat (5 g) using the procedure of Uttaro *et al.* (1993), with minor modifications. These were placed in preweighed centrifugal microfilters (Centrex glass fiber filter, Schleicher & Schuell, USA) without the collection vial, and weighed. The vial was attached, and tubes centrifuged at 2,000 *g* for 15 min. The collection vial containing the expressed fluid was removed, and tubes reweighed, enabling water loss to be calculated by difference. WHC (%) was calculated as the percentage of remaining water content of meat samples after centrifugation.

TBARS (2-thiobarbituric acid reactive substance)

TBARS values were determined at various storage times. The TBARS of samples were analyzed by the modification method described by the procedure of Ahn *et al*. (1998). A 5 g pork sample was homogenized using a homogenizer (Polytron PT 10-35 GT, Kinematica Co., Switzerland) with 15 ml of distilled water for 2 min and then transferred to 100 ml falcon tube. 1 ml of solution was placed in test tubes and 50 ml buylated hydroxytoluene (7.2% in ethanol, w/v) and 2 ml thiobarbituric acid/ trichloroacetic acid solution (20 mM TBA/15%, w/v) were added to the tubes. The mixture was vortexed and then boiled in a 90°C boiling water bath for 15 min to develop color. The sample was cooled in cold water for 10 min, and centrifuged for 15 min at 3,000 *g*. The absorbance of the resulting supernatant solution was determined at 531 nm against a blank containing all the reagents minus the sample. One mL of distilled water was added to test tube and mixed with 2 mL of TBA/TCA solution for blank sample. The TBARS was determined in triplicate on each pork belly product. The amount of color was measured in a UV spectrophotometer (T60 U., Karaltay Scientific Instruments Co., China). The results were expressed as mg malonaldehyde/kg sample.

Fatty acid analysis

Total fat for fatty acid analysis was extracted according to the method of Folch *et al.* (1957). After thawing the samples, the lipids in a 5 g sample were extracted in chloroform/methanol (2:1), with BHT as an antioxidant (Bligh and Dyer, 1959). The methyl esters from fatty acids (FAMES) were formed using a KOH solution in methanol. The fatty acid methyl esters (FAME) were extracted with water and hexane. The top hexane layer containing FAME was dehydrated through the anhydrous Na_2SO_4. The extracted and dehydrated hexane was transferred to a vial to be analyzed.

Separation and quantification of the fatty acid methyl esters was carried out using a gas chromatograph (GC, Agilent 7890N, Agilent Technologies Seoul, S.L., Korea) equipped with a flame ionization detector automatic sample injector HP 7693, and using a DB-WAX fused silica capillary column (30 m, 0.25 mm i.d., 0.2 mm film thickness, Agilent Technologies Seoul, S.L., Korea). Helium was used as carrier gas at linear flow of 1 ml/min and the injection volume was 1 ml. The oven temperature was initially held at 180°C for 1 min then increased at 2.5°C / min to 230°C and held for 12 min. The injector (split mode) and detector temperatures were maintained at 280°C. Linoleic acid (C18:2) was used as an internal standard (catalogue number H3500, Sigma-Aldrich Inc. 595 North Harrison Road, Bellefonte, PA 16823-0048, USA). The FAME in the total lipids were identified by comparison of the retention times with those of a standard FAME mixture (SuplecoTM 37 Component FAME Mix, Catalogue number 47885-UP, Lot number, LB-85684. Sigma-Aldrich Inc. North Harrison Road, Bellefonte, PA 16823-0048, USA). Fatty acids were exp- ressed as a percentage of total fatty acids identified and grouped as follows: SFA, MUFA and PUFA. PUFA/SFA and n-6/n-3 ratios were calculated.

Sensory evaluations

The samples were cut into 20×20×10 mm thickness and were cooked in electrical grill (Nova EMG-533, 1,400W, Evergreen enterprise, Korea) for 1 min. Core temperature of the samples during heating was 100±2°C.

During the sensory training sessions there was both discussion and sensory assessment of representative samples. The attributes color, flavor, juiciness, tenderness and acceptability were assessed. The sensory scores were evaluated independently by 20 trained sensory panelists for random cubes of each sample using a nine-point quantitative descriptive method, varying from dislike/weak extremely (score 1) to like/strong extremely (score 9). The mean value from three repeated measurements was determined.

Statistical methods

An analysis of variance were performed on all the variables measured using the General Linear Model (GLM) procedure of the SAS statistical package (SAS, 1999). The Duncan's multiple range test (p<0.05) was used to determine differences among the treatment means.

Table 1. pH, moisture and fat content of loins and bellies from different three-way crossbreds

	YLD[1]	YCY	YBD	SEM[2]
		-Loin-		
pH	5.85	5.86	5.84	0.02
Moisture (%)	73.25	73.97	73.70	0.18
Fat (%)	3.33[a]	2.81[ab]	2.55[b]	0.17
		-Belly-		
pH	5.70	5.88	5.88	0.03
Moisture (%)	48.38[b]	57.77[a]	51.93[ab]	1.48
Fat (%)	28.36	25.24	28.54	1.26

[1]YLD, Yorkshire × Landrace × Duroc; YCY, Yorkshire × Chester White × Yorkshire; YBD, Yorkshire × Berkshire × Duroc
[2]Standard error of the means (n=20)
[a-b]Figures with different letters within the same row differ significantly (p<0.05)

Results and Discussion

Physicochemical characteristics

Pork quality characteristics in the loins and bellies of three-way crossbreeding pigs are presented in Table 1. There were no differences observed in pH and moisture contents in the loins among the crossbreeding pigs. The fat contents of the loins were higher in YLD than in the other crosses (p<0.05). YBD had the lowest fat content. Jin *et al.* (2005) observed that the loins from the LYD pigs had lower intramuscular fat (IMF) contents compared to those from YBB. Crossbred differences in moisture contents were significant (p<0.05) in the belly muscles. The moisture contents of the bellies were higher in YCY than in the other crosses. YLD in the bellies had the lowest. Previous studies have shown that there was no difference in pH value between LYD and YBB (Jin *et al.*, 2005). In case of fat contents, YCY in belly was the lowest value. However, there were no differences observed in fat contents among the crossbreeding pigs. In the present study, intramuscular fat content of three-way crossbreds ranged from 25% to 28% in bellies. Kim *et al.* (2007) investigated that there were no significant differences in moisture and fat contents in the bellies among the crossbreeding pigs.

As shown in Table 2, WHC of the loins were higher in YCY than in the other crosses (p<0.05). Many research have shown that WHC of pork bellies among the crossbreeding ranged from 52% to 79%, which is similar to the our results (Kim *et al*., 2006). However, there were no differences observed in the bellies among the crossbreeding pigs. Warner–Bratzler shear force value is a moderate indicator of tenderness and texture (Essen-Gustavsson *et al*., 1994). Shear force value of the loins were higher in YBD than in the other crosses (p<0.05). YLD in the loin had the lowest. This may be due to its lower fat content in loin samples. YCY in belly was the lowest shear force value. Jin *et al.* (2005) suggested that the YBB had lower shear force value and cooking loss than LYD.

Table 2. Drip loss, cook loss, shear force, water holding capacity (WHC) of loins and bellies from three-way crossbreds

	YLD[1]	YCY	YBD	SEM[2]
		-Loin-		
Drip loss (%)	2.00	2.58	2.02	0.20
Cook loss (%)	12.59	12.19	12.02	0.53
WHC (%)	73.16[b]	78.41[a]	71.65[b]	0.95
Shear force (kg)	4.34[b]	5.27[ab]	6.01[a]	0.25
		-Belly-		
Drip loss (%)	0.63	0.70	0.86	0.08
Cook loss (%)	9.95	8.89	9.39	0.29
WHC (%)	72.42	75.00	70.86	1.16
Shear force (kg)	5.03	5.88	5.94	0.38

[1]YLD, Yorkshire × Landrace × Duroc; YCY, Yorkshire × Chester White × Yorkshire; YBD, Yorkshire × Berkshire × Duroc
[2]Standard error of the means (n=20)
[a-b]Figures with different letters within the same row differ significantly (p<0.05)

Table 3. TBARS values (mg MDA/kg meat) of loins and bellies from different three-way crossbreds during storage

Crossbred[1]	Storage (days)			SEM[2]
	0	7	14	
		-Loin-		
YLD[1]	0.84[ay]	1.03[x]	1.08[x]	0.10
YCY	0.51[bz]	0.77[y]	1.01[x]	0.12
YBD	0.78[a]	0.97	0.87	0.09
SEM	0.04	0.05	0.04	
		-Belly-		
YLD	0.59	0.56	0.59	0.10
YCY	0.56[y]	0.58[xy]	0.63[x]	0.10
YBD	0.59	0.60	0.62	0.09
SEM	0.01	0.02	0.01	

[1]YLD, Yorkshire × Landrace × Duroc; YCY, Yorkshire × Chester White × Yorkshire; YBD, Yorkshire × Berkshire × Duroc
[2]Standard error of the means (n=20)
[a-b]Figures with different letters within the same column differ significantly (p<0.05)
[x-z]Figures with different letters within the same row differ significantly (p<0.05)

TBARS value is the most common indicator used to measure the degree of lipid oxidation in meat products (Chen *et al*., 2004). As presented in Table 3, TBARS value increased during storage for all three crossbreds. It is normally accepted that TBARS value increases in meat with increasing storage time (Yang *et al*., 2009). TBARS value in YCY increased with increasing storage time in bellies

Table 4. Fatty acid composition (%) of loins and bellies from different three-way crossbreds

	Loin				Bellies			
	YLD[1]	YCY	YBD	SEM[2]	YLD	YCY	YBD	SEM
C16:0	24.68	24.15	24.32	0.18	23.68	23.26	23.74	0.21
C16:1	2.94	3.01	2.94	0.08	2.00	2.42	2.34	0.10
C18:0	12.12	12.40	12.68	0.17	11.76	11.34	11.89	0.21
C18:1	39.99	40.19	38.55	0.33	41.19	41.25	40.38	0.32
C18:2	10.82	10.18	11.13	0.33	12.06	11.77	12.60	0.27
C18:3	0.48	0.39	0.44	0.02	0.77	0.71	0.79	0.02
C20:4	1.67	1.90	2.07	0.10	0.36	0.40	0.38	0.02
SFA[3]	36.80	36.54	37.02	0.28	35.44	34.60	35.63	0.28
UFA	55.90	55.68	55.12	0.25	56.37	56.55	56.49	0.33
PUFA	12.97	12.48	13.63	0.41	13.18	12.88	13.77	0.29
MUFA	42.93	43.20	41.49	0.35	43.19	43.67	42.72	0.36
UFA/SFA	0.66	0.66	0.67	0.01	0.63	0.61	0.63	0.01
P/S	0.35	0.34	0.37		0.37	0.37	0.39	

[1]YLD, Yorkshire × Landrace × Duroc; YCY, Yorkshire × Chester White × Yorkshire; YBD, Yorkshire × Berkshire × Duroc
[2]Standard error of the means (n=20)
[3]SFA, saturated fatty acids; PUFA, polyunsaturated fatty acids; MUFA, monounsaturated fatty acids

(p<0.05). The TBARS value in loins was significantly lower in YCY than the others on day 0. The results might be due to the fact that YCY had less oxidative fiber type than others and which are consequently reflected lower TBARS. In other words, YCY could be less susceptible to lipid oxidation, and therefore, to the development of rancidity. Despite of different fat contents, lipid oxidation was mostly affected by storage time.

Fatty acid composition

Fatty acid composition in the loins and bellies of three-way crossbreeding pigs are presented in Table 4. The major fatty acids in the loin and belly muscles (listed from most prevalent to least) were oleic (C18:1), palmitic (C16 :0), stearic (C18:0), linoleic (C18:2), palmitoleic (C16:1), arachidonic (C20:4) and linolenic (C18:3) acids. These seven fatty acids accounted for over 95% of the total fatty acids in the IMF. Crossbred effects on fatty acid composition were no significant (p>0.05) for the fatty acid composition (Table 5). In the present study, YCY loins and bellies had higher percentage of oleic acid (C18:1) and MUFA than the other crosses. PUFA content was higher in loin and belly muscles from YBD than from YLD and YCY, which showed the highest percentages of C18:2, C18:3, and C20:4. MUFA was mostly composed of oleic acid (C18:1). The sum of MUFA and PUFA is associated with a possibility of oxidation, rancidity, softness, and texture of the fat, as the number of double bonds in fatty acids increases and their melting point and oxidative stability are reduced (Wood *et al.,* 1999). Fatty acid composition is affected by genetic and environmental factors, which include diet, sex, age, and genotype (Brewer *et al*., 2001). Meat is a major source of fat including SFA in the human diet (Wood *et al*., 2003). Generally, excessive intake of SFA has been considered as the main factor for cancer and coronary heart disease, although C18:0 is considered as a neutral fatty acid (Webb and O'Neill, 2008). WHO recommends reducing the intake of SFA and increasing the intake of n-3 PUFA. The minimum P/S ratio for human nutrition is at least 0.45 (Simopoulos, 2004) and generally should be around 0.7 (Raes *et al*., 2003). In the present experiment, the P/S ratios in different crossbreds were lower than in the above recommendation. Our results show that YLD pigs in loin and belly had better WHC, low shear force and higher fat content, therefore, obtained the highest sensory evaluation. The results of the present study indicate meat quality and sensory evaluation can be altered by three-way crossbreeding from the loin and belly muscles. However, the reasons for these crossbreeding muscle differences are so complex. Therefore, further research using pig crossbreds is required to identify and verify on quality in pork loin and belly muscles.

Sensory evaluation

Sensory evaluation in the muscles of three-way crossbreeding pigs is presented in Table 5. Sensory evaluation was affected by crossbreeding in loin and belly muscles. Flavor, tenderness, juiciness and acceptability were higher in YLD than the others in loin and belly muscles (p< 0.05). Flavor is one of the most important qualities of meat and meat products. Raw meat possesses only a serum-like flavor, with the characteristic flavor components being

Table 5. Sensory evaluation of loins and bellies from different three-way crossbreds

	YLD[2]	YCY	YBD	SEM[3]
		- Loin -		
Color[1]	5.38	5.25	4.53	0.16
Flavor	5.34[a]	4.75[b]	4.75[b]	0.21
Tenderness	6.00[a]	4.93[b]	5.11[b]	0.26
Juiciness	5.39[a]	4.90[b]	4.83[b]	0.23
Preference	5.19[a]	4.73[b]	4.56[b]	0.27
		- Belly -		
Color	6.03[a]	5.58[b]	5.56[b]	0.14
Flavor	6.16[a]	5.25[b]	5.44[b]	0.19
Tenderness	6.38[a]	5.58[b]	5.97[b]	0.16
Juiciness	6.53[a]	5.80[b]	5.83[b]	0.15
Preference	6.16[a]	5.95[b]	5.81[b]	0.16

[1]1, extremely bad ~ 9, extremely good
[2]YLD, Yorkshire × Landrace × Duroc; YCY, Yorkshire × Chester White × Yorkshire; YBD, Yorkshire × Berkshire × Duroc
[3]Standard error of the means (n=20)
[a-b]Figures with different letters within the same row differ significantly (p<0.05)

produced during the heating process (Hilmes and Fischer, 1997). In addition, the amount and type of fat in meat influence two major components of meat quality, i.e., tenderness and flavor (Wood *et al*., 1999). The sensory evaluation could be affected by fat contents. In the present study, YLD pigs obtained more sensory scores and this was due to its higher fat content and lower shear force value, which could have positive effects on the sensory traits of pork. The results showed that there were observed differences in eating quality between the crossbreds.

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