



## Quality Characteristics of Dry-cured Ham Made from Two Different Three-way Crossbred Pigs

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**ABSTRACT:** This study was conducted to compare the physicochemical traits of dry-cured hams made from two different three-way crossbred pigs: Yorkshire×Landrace×Duroc (YLD) and Yorkshire×Berkshire×Duroc (YBD). Animals were slaughtered at a live weight of 110 to 120 kg and cooled at 0°C for 24 h in a chilling room, the ham portion of the carcasses were cut and processed by dry-curing for physico-chemical analyses. While the moisture and crude protein contents of dry-cured ham were higher in YLD than in YBD, crude fat and ash content were higher in YBD ( $p<0.05$ ). The salt contents of ham from YBD were higher than those from YLD ( $p<0.05$ ). YBD ham samples showed a higher  $L^*$  and  $b^*$  values than those from YLD, while YBD ham showed lower  $a^*$  value ( $p<0.05$ ). Thiobarbituric acid reactive substances (TBARS) and volatile basic nitrogen (VBN) values of YLD hams were lower than those of YBD samples ( $p<0.05$ ). Hardness, gumminess, chewiness, and shear force values of YBD ham were higher than those of YLD sample ( $p<0.05$ ). Saltiness was significantly higher in YBD ham than in YLD samples ( $p<0.05$ ). YLD ham displayed a superior quality than YBD. Considering the meat quality parameters of two-way crossbred ham, YLD hams could be more suitable for the production of dry-cured products. (**Key Words:** Crossbred Pig, Dry-cured Ham, Physico-chemical Trait)

### INTRODUCTION

Dry-cured ham is one of the oldest cured meat products, which is made from whole leg of pork or other whole muscle (Jin et al., 2012). This is favorable to consumers due to the particular sensory characteristics and physicochemical and biochemical changes that take place during ripening period (Cava et al., 1999). The raw material is a decisive factor in the quality of dry-cured ham and depends on several factors, such as genetics type, sex, feeding, and rearing system (Hui et al., 2004).

Crossbreeding in pig production is aimed to increase the total efficiency and also to improve the quantity and quality of the meat (Sellier, 1998). Nowadays, the majority of pig production is based on crossbreds and generally is three-way crosses with Landrace×Yorkshire×Duroc (LYD) in Korea. These crossbreds have an excellent growth rate,

higher yields and bigger litter size than other crossbreds (Lim et al., 2014). Individual breeds of pigs have their own different traits. Berkshire has both an excellent water holding capacity and higher amino acid contents. On the other hand, Duroc breed has both an excellent growth rate and a higher fat content relative to the Landrace and Yorkshire. Landrace pigs have a thin subcutaneous fat layer, large hams and high muscularity in the carcass (Lim et al., 2014). Traditionally, common crossbreeding used in Europe for the production of high quality dry-cured ham is Yorkshire×Berkshire×Duroc (YBD).

Different genetic groups of pigs have been used to obtain fresh hams with ideal quality traits and, in particular, crossbreds often satisfies both muscle and fat quality criteria for dry-ham processing (Sabbioni et al., 2004). Parameters, such as texture, color and intramuscular fat, are used as quality indicators of dry-cured ham (Ruiz-Ramirez et al., 2006). Dry-cured ham has been largely studied for its physico-chemical and sensory properties and for the variation of its sensory quality depending on processing technologies (Andrés et al., 2004; Serra et al., 2005). It is worthwhile to investigate the meat quality of different types

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of crossbreeds required to fulfill the diversity of consumers' options. However, very few studies have been made on the quality characteristics of dry-cured hams from three-way crossbreeds: YLD and YBD. Therefore, the aim of this study was to assess the influence of crossbreeding on the quality traits of dry-cured ham, as well as acceptability of dry-cured hams produced from these pigs.

## MATERIALS AND METHODS

### Animals, sample collection and processing of the hams

A total of 20 gilts, 180 days old, were evaluated from crossbreeding schemes which included YLD and YBD with animals in each scheme. The pigs were born and raised at swine farms. Animals were fed the same commercial feed including the fattening period from weaning weight (30 kg) to slaughter weight (90 kg). These pigs were housed in partially slotted and concrete floor pens having a pen size of 3.5 m×3.5 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 17% protein, 2.4% fat and 3,250 kcal/kg metabolic energy. Pigs from each crossbred were randomly selected from 110 to 120 kg range of marketing weight, slaughtered, and cooled at 0°C 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°C for 60 days. After salting, the samples were soaked in cold water and washed. Subsequently, hind legs were dried for 60 days at 20°C ±3°C and at 80% to 100% RH. Finally, they were ripened for 60 additional days at 10°C±6°C and at 65% to 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 the homogenized sample, in triplicate.

### Proximate composition and pH

The proximate composition was obtained with a slightly modified method of AOAC (AOAC, 2000). 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., 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, Beverly, MA, 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. Water activity of ham was determined with a water activity meter (Handheld instrument HP23-AW-A Instrument, Rotronic AG, Zurich, Switzerland).

### Water-holding capacity, salt content and meat color

Water-holding capacity was measured using the method of Ryoichi et al. (1993), with minor modifications. Samples were placed in preweighed centrifugal microfilters (Centrex glass fiber filter, Schleicher & Schuell, St. Louis, MO, 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. The water holding capacity (%) was calculated as the percentage of remaining water content of meat samples after centrifugation.

Salt content was determined by a digital analyzer (PAL-03S, ATAGO, Tokyo, Japan). The surface color value of the samples were measured using the Commission Internationale de l'Eclairage L\*, a\* and b\* system using a Minolta chromameter (Model CR-410, Minolta Co., Tokyo, 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.

### Thiobarbituric acid reactive substances and volatile basic nitrogen values

The thiobarbituric acid reactive substances (TBARS) values of samples were analyzed by the modified method described by Witte (1970). A dry-cured ham sample of 5 g was weighed into a 50 mL test tube and homogenized with 15 mL of deionized distilled water using the Polytron homogenizer for 15 s at the highest speed (T25basic, IKA, Selangor, Malaysia). The ham sample homogenate (2 mL) was transferred to a disposable test tube (13×100 mm<sup>2</sup>), and a butylated hydroxyanisole (10%, 50 mL) and thiobarbituric acid/trichloroacetic acid (TBA/TCA) solution (4 mL) were added. The sample was mixed using a vortex mixer, and it was then incubated in a boiling water bath for 15 min to develop color. The sample was cooled and determined at 531 nm against a blank containing 2 mL of deionized distilled water and 4 mL of TBA/TCA solution. The amounts of TBARS were expressed in mg of malondialdehyde (MDA) per kg of sample. The micro-

diffusion method described by Conway (1950) was modified for the determination of volatile basic nitrogen values (VBN) in the dry-cured ham samples. Each ham sample (3 g) was homogenized (Ultra-turrax T25-S1, IKA, Staufen, Germany) for 30 s with 27 mL of distilled water. The supernatant solution was filtered using a filter paper (No.4, Whatman, St. Louis, MO, USA). Ten mL of 20 g/L boric acid was placed on the inner section of a Conway micro-diffusion cell (Sibata Ltd., Tokyo, Japan). Then 1 mL of sample solution and 1 mL of saturated  $K_2CO_3$  solution were also placed on the outer section of the same cell, and the lid was immediately closed. The cell was incubated at 25°C for 60 min, and it was then titrated against 0.02 N  $H_2SO_4$ . The VBN value was calculated by the following equation:

$$\text{VBN mg \% (mg/100 g sample)} \\ = [(a-b) \times f \times 28.014] / S \times 100$$

Where S is the meat sample weight in grams, b is the volume of added  $H_2SO_4$  in blank in mL, a is the volume of added  $H_2SO_4$  in the sample in mL, and f is the standard factor of  $H_2SO_4$ .

#### Instrumental texture analysis

Texture measurements in the form of texture profile analysis (TPA; Bourne, 1978) of the hams were performed at room temperature with a TA-XT2 Texture Analyzer (Stable Micro Systems, Godalming, UK) with a 2,500 N load cell. The Texture Expert, version 1.20 (Spanish), computer program by Stable Micro Systems was used for data collection and calculations. The samples were 1 cm in height and 1.5 cm in diameter. Each sample was compressed axially in two consecutive cycles of 50% compression with a flat plunger 50 mm in diameter (P50), with 5 s between cycles. The cross-head moved at a constant speed of 1 mm/s. The following texture parameters were measured from force-deformation curves: hardness, springiness, cohesiveness, gumminess and chewiness. Shear force values (kg) were also analyzed with the same analyzer.

#### Sensory evaluations

All the samples, with 1.5 mm thickness, were evaluated at 20°C to 22°C in a sensory panel room. About 50 mL of water and 20 g of unsalted bread were provided to assessors between successive ham samples. During the sensory training sessions there were both discussion and sensory assessment of representative samples. The attributes flavor, juiciness, tenderness, saltiness and acceptability were assessed. The sensory scores were evaluated independently by 10 trained sensory panelists for random cubes of each sample using a seven-point quantitative descriptive method,

varying from very low (score 1) to very high (score 7).

#### Statistical methods

An analysis of variance was performed on all the variables measured using the general linear model procedure of the SAS statistical package (SAS Institute Inc., 2002). 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

#### Physico-chemical characteristics

Comparison of proximate composition of dry-cured ham made from YLD and YBD is shown in Table 1. Crossbred differences in proximate composition were found ( $p < 0.05$ ). While the moisture and crude protein contents of dry-cured ham were higher in hams made from YLD than in YBD, crude fat and ash contents were higher in YBD. Seong et al. (2008) reported that the moisture, fat and protein contents of the muscles *biceps femoris* from cooked dry-cured ham were 66.9%, 7.3%, and 22% respectively. Fuentes et al. (2014) observed that moisture and fat content of the muscle *biceps femoris* from dry-cured hams produced from crossbred ranged from 48% to 51% and from 5.7% to 7.1%, respectively. Ventanas et al. (2006) showed that the genetic background significantly affects the proximate composition of dry-cured hams. Kim et al. (2007) stated that the butts from the Berkshire×Duroc (BD) had higher fat contents than Yorkshire×Landrace×Berkshire (YLB) and YLD. Fat content is believed to be one of the most crucial quality traits of cured hams. Jiménez-Colmenero et al. (2010) mentioned that the higher the fat content, the greater the acceptability of dry-cured hams.

The water activity of dry-cured hams made from crossbreeds ranged from 0.84% to 0.85% in this study. Similar values were found for dry-cured hams by Jin et al. (2012). Lorenzo et al. (2008) suggested that the water activity values of dry-cured meat products decreased progressively and significantly throughout the whole manufacturing process. The water activity is useful to

**Table 1.** Proximate composition (%) of dry-cured ham made from two different three-way crossbred pigs

Variable	Crossbred	
	YLD <sup>1</sup>	YBD
Moisture	56.00±0.60 <sup>a</sup>	53.89±0.60 <sup>b</sup>
Crude protein	28.04±0.05 <sup>a</sup>	26.87±0.07 <sup>b</sup>
Crude fat	3.24±0.21 <sup>b</sup>	6.17±0.63 <sup>a</sup>
Crude ash	11.86±0.03 <sup>b</sup>	13.00±0.02 <sup>a</sup>

YLD, Yorkshire×Landrace×Duroc; YBD, Yorkshire×Berkshire×Duroc.

Values are mean±standard deviation.

<sup>a,b</sup> Means with different letters within a same row differ significantly ( $p < 0.05$ ).

describe the equilibrium state of dry-cured ham, and hams must have a stable water activity value to avoid changes in quality during storage (Jin et al., 2012). Many researchers have indicated that the production of lactic acid in tissue leads to a reduction in pH of meat, which leads to a reduced amount of water (Lorenzo et al., 2008). Salt, which is a multifunctional ingredient in dry-cured ham elaboration, affects both quality and safety. YBD ham contained a much higher salt content than YLD ( $p < 0.05$ ). The NaCl final concentration depends on the degree of dryness at the end of ripening (Zanardi et al., 2010).

Regarding color measurement, YBD ham samples showed a significantly higher  $L^*$  and  $b^*$  values than YLD, while YBD ham showed a lower  $a^*$  value ( $p < 0.05$ ). Lightness is related to the thin aqueous layer on the muscle's surface (Hunt, 1980). These results suggest that lightness in these muscles depends on the water content (moisture) and water movement (dehydration) towards the surface (Marusic et al., 2011).

Lipid oxidation measured as TBARS is a major factor in reducing quality and acceptability of meat products (Morrissey et al., 1998). As presented in Table 2, YBD ham showed significantly higher TBARS value than YLD samples ( $p < 0.05$ ). This indicates that YBD ham is more susceptible to lipid oxidation than YLD (Lim et al., 2014). This could be explained by the fact YLD had less oxidative fiber type than YBD. NaCl has a significant pro-oxidant effect in meat and meat products and salt accelerates lipid oxidation but the mechanism of action is not fully elucidated (Kanner et al., 1991). However, there is evidence that chloride ions may displace iron ions from binding macromolecules and make them available as initiators of lipid peroxidation (Kanner et al., 1991). The VBN value of the YLD sample was significantly lower than that of the

**Table 2.** Quality traits of dry-cured ham made from two different three-way crossbred pigs

Variable	Crossbred	
	YLD	YBD
pH	5.83±0.01	5.74±0.01
Water holding capacity	24.36±0.51	23.70±0.75
Water activity	0.85±0.05	0.84±0.03
Salt content (%)	14.15±0.07 <sup>b</sup>	17.30±0.01 <sup>a</sup>
CIE $L^*$	49.02±0.46 <sup>b</sup>	53.33±0.91 <sup>a</sup>
CIE $a^*$	14.12±0.35 <sup>a</sup>	12.43±0.31 <sup>b</sup>
CIE $b^*$	1.27±0.22 <sup>b</sup>	2.84±0.22 <sup>a</sup>
TBA (mg malonedialdehyde/kg)	2.02±0.13 <sup>b</sup>	2.34±0.13 <sup>a</sup>
VBN (mg/%)	44.65±0.49 <sup>b</sup>	51.67±0.50 <sup>a</sup>

YLD, Yorkshire×Landrace×Duroc; YBD, Yorkshire×Berkshire×Duroc; CIE, Commission Internationale de l'Éclairage; TBA, thiobarbituric acid; VBN, volatile basic nitrogen.

Values are mean±standard deviation.

<sup>a,b</sup> Means with different letters within a same row differ significantly ( $p < 0.05$ ).

**Table 3.** Texture profile of dry-cured ham made from two different three-way crossbred pigs

Variable	Crossbred	
	YLD	YBD
Hardness (kg)	29.90±1.31 <sup>b</sup>	33.15±0.61 <sup>a</sup>
Springiness (mm)	0.50±0.13	0.60±0.08
Cohesiveness (mm)	0.65±0.08	0.68±0.03
Gumminess (mm)	19.34±0.77 <sup>b</sup>	20.77±0.33 <sup>a</sup>
Chewiness (mm)	9.56±0.32 <sup>b</sup>	11.70±0.91 <sup>a</sup>
Shear force (kg)	14.76±0.51 <sup>b</sup>	18.48±0.48 <sup>a</sup>

YLD, Yorkshire×Landrace×Duroc; YBD, Yorkshire×Berkshire×Duroc.

Values are mean±standard deviation.

<sup>a,b</sup> Means with different letters within a same row differ significantly ( $p < 0.05$ ).

YBD ( $p < 0.05$ ). The VBN is an important index for estimation of meat freshness, because it is increased by the levels of microbial contamination (Lee and Joo, 1999).

### Texture profile and sensory evaluations

For texture profile analysis, hardness, gumminess, chewiness, and shear force values were significantly higher in YBD ham than in YLD samples ( $p < 0.05$ ), as shown in Table 3. Texture is a major sensory characteristic in dry-cured ham quality evaluation. The main texture defects in dry-cured ham are excessive softness inside (Parolari, 1996). Numerous studies have demonstrated that negative correlations between moisture content and texture profile including hardness, gumminess and chewiness (Virgili et al., 1995; Monin et al., 1997; Serra et al., 2005). Similar finding was reported by Hui et al. (2004), who found that *Biceps femoris* muscles from hams with a higher salt content were the higher hardness. Warner-Bratzler shear force value is a moderate indicator of chewiness.

In case of sensory properties, there were no significant differences between YBD and YLD samples except the saltiness (Table 4). Saltiness was significantly higher in YBD ham than in YLD samples ( $p < 0.05$ ). Salt is not the only factor determining salty taste. This attribute can also be influenced by other kind of compounds such as amino

**Table 4.** Sensory evaluations of dry-cured ham made from two different three-way crossbred pigs

Variable	Crossbred	
	YLD	YBD
Tenderness	2.60±0.52 <sup>1</sup>	2.20±0.42
Flavor	3.00±0.82	3.30±0.95
Juiciness	3.60±0.97	3.50±0.85
Saltiness	5.80±0.79 <sup>b</sup>	7.40±0.70 <sup>a</sup>
Overall acceptability	3.40±0.97	3.20±0.79

YLD, Yorkshire×Landrace×Duroc; YBD, Yorkshire×Berkshire×Duroc.

<sup>1</sup> 1: extremely low to 7: extremely high.

Values are mean±standard deviation.

<sup>a,b</sup> Means with different letters within a same row differ significantly ( $p < 0.05$ ).

acids or nucleotides having a salty taste or a low proportion of intramuscular fat (Buscailhon et al., 1995). Ventanas et al. (2006) confirmed that crossbreeding influence both consumer preference and juiciness ranking. Intramuscular fat plays a decisive role in most features of dry-cured products directly linked to their sensory characteristics, such as marbling and juiciness (Ruiz et al., 2002). However, sensory characteristics appeared to be not related to higher fat content in this study. Further research should be required to verify on the meat quality of crossbred hams.

### CONCLUSION

It can be concluded that two different three-way crossbreeding altered meat quality to some extent. It is conceivable that dry-cured hams from YLD pigs showed relatively desirable meat quality parameters in terms of higher moisture and protein and less TBARS and VBN. The present study confirms that YLD hams could be more suitable for the production of dry-cured products. The result of this study indicates that the meat quality of dry-cured ham could be improved by pig crossbreeding.

### CONFLICT OF INTEREST

We certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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