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Carcass and meat quality traits of four commercial pig crossbreeds in China

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ABSTRACT. We evaluated carcass and meat quality traits of two Chinese native crossbreeds Landrace x Meishan (LM) and Duroc x (Landrace x Meishan) (DLM) and two foreign crossbreeds Duroc x (Landrace x Yorkshire) (DLY) and PIC (an imported five-way crossbreed). One hundred and twenty weaned pigs (half castrated males and half females) were reared and slaughtered at a predestinated slaughter age. The general carcass and meat quality traits were measured and analyzed. The DLY and PIC crosses had significantly heavier live weights (93.39 and 96.33 kg, $P < 0.01$), significantly higher dressing percentages (80.65 and 79.39%, $P < 0.05$), significantly bigger loin areas (42.69 and 43.91 cm^2, $P < 0.001$), and significantly more lean carcasses (65.78 and 66.40%, $P < 0.001$) than LM and DLM. On the other hand, LM had a significantly lower live weight (70.29 kg, $P < 0.01$), significantly thicker back fat (3.54 cm, $P < 0.001$), significantly less lean carcasses (46.82%, $P < 0.001$), and significantly less ham and breech (26.53%, $P < 0.05$) than the other crossbreeds. Among meat quality parameters, LM had the highest intramuscular fat content (5.02%, $P < 0.001$) and the smallest fiber area (3126.45 μm^2, $P < 0.01$). However, PIC showed the lowest pH_1 (5.82, $P < 0.01$) and pH_2

(5.63, P < 0.01), the highest drip loss (2.89%, P < 0.01), and the lowest intramuscular fat (1.35%, P < 0.001). We concluded that LM and DLM had good meat quality traits but poorer carcass traits than DLY and PIC; DLY had good carcass and meat quality traits; PIC had good carcass traits, but it had less intramuscular fat, lower pH and higher drip loss.

Key words: Crossbred pig; Carcass traits; Meat quality

INTRODUCTION

For many years, a major objective of the swine industry has been to increase the carcass meat percentage (Cameron, 1990). Genetic selection has enabled dramatic improvements in the carcass composition of pigs (Latorre et al., 2003b, 2008). Today, meat quality has become a primary focus for pig production (Newcom et al., 2004). Crossbreeding is extensively used in pig production to increase the total efficiency of pig production (Bennet et al., 1983). Accordingly, when choosing the best animal crossbreeding strategy, it is important to recognize that carcass and meat quality traits depend on the crossbreed.

The Chinese swine industry is by far the largest of its kind in the world. Jiang and Li (2012) reported the 2011 standing population to be 471 million heads and the slaughter population to be 641 million in China. There are about 100 indigenous swine breeds in China, and these have high reproductive rates, good meat quality, good adaptability to extensive feeding and management, and the ability to utilize green crude. However, due to undesirable traits, such as slow growth rate, low dress percentage, and low lean meat percentage, pure local breeds have been scarcely utilized on commercial farms in China. Rather, most small commercial farm production involves two-way or three-way crossbreeds with local breeds (Jones, 1998). The Meishan pig is famous for high reproductive rates and is a traditional Chinese indigenous breed that is extensively utilized in commercial pig population by two-way or three-way crossbreeding systems. The most popular crossbreeding scheme utilizes Landrace x Meishan or Landrace x Meishan F_1 sows bred to a terminal Duroc boar. Nearly all modernized swine farms use entirely imported breeding stocks, and the most popular crossbreeding scheme utilizes Landrace x Yorkshire F_1 sows bred to a terminal Duroc boar. In addition, the PIC pig (an imported five-way crossbred from Pig Improvement Co., Ltd.) is popular in the Chinese swine industry. It is important to collect complete carcass and meat quality traits of crossbreeds used in the current swine industry.

Therefore, the objectives of this study were to investigate carcass and meat quality traits among the representative crossbreeds used in our commercial pig population. The crossbreeds were composed of two native crossbreeds, Landrace x Meishan and Duroc x (Landrace x Meishan), and two foreign crossbreeds, Duroc x (Landrace x Yorkshire) and PIC.

MATERIAL AND METHODS

This study was conducted in compliance with the requirements of the Animal Ethics Committee of Sichuan Agricultural University.

Animals and management

The study was organized by Sichuan Dayu Company and Sichuan Agricultural University and conducted on the farm of Sichuan Dayu Company in Mianyang City. A total of 120 weaned pigs (half castrated males and half females) representing two native crossbreeds, Landrace x Meishan (LM, N = 20) and Duroc x (Landrace x Meishan) (DLM, N = 20), and two foreign crossbreeds, Duroc x (Landrace x Yorkshire) (DLY, N = 40) and PIC (N = 40), were randomly selected at 35 days of age. Animals with similar weights were selected in every crossbreed. Animals were housed in pens of four animals during experimental periods under similar conditions. All pigs were fed twice daily with the same diet, and pigs had *ad libitum* access to food and water (nipple drinkers). The feeding experiment lasted for 150 days after a 7-day adaptation period. The experimental diets were based on corn and soybean meal and were formulated with crude protein concentrations, trace minerals, and vitamins for the two different growth phases. From the beginning of the experiment until day 60 of the experiment, the pigs were fed a diet containing 14.0 MJ/kg of metabolizable energy and 18% crude protein (9.0 g/kg lysine). From day 60 of the experiment to the predetermined slaughter age, they received a diet containing 13.5 MJ/kg of metabolizable energy and 16.0% crude protein (8.0 g/kg lysine).

Carcass measurements

At their predetermined slaughter age, all pigs were transported to the nearby slaughterhouse to determine carcass composition according to the methods described by Xiao et al. (1999). Briefly, the pigs received no feed on the day of slaughter and were allowed to rest for 2 h after about 1 h of transportation (including loading and unloading), after which they were electrically stunned (90 V, 10 s, and 50 Hz), exsanguinated, dehaired, and eviscerated. The head was removed, and the carcass was split longitudinally. Loin area was determined by tracing its surface area at the tenth rib and by using a planimeter (Planix 5.6, Tamaya Digital Planimeter, Tamaya Tecnics Inc., Tokyo, Japan). The average of three back-fat thickness measurements was taken on the first rib, last rib, and last lumbar vertebra along the midline with a sliding caliper. Ham and breech were cut from the left carcass, and bone, muscle, subcutaneous fat, and skin were physically dissected. Each of the dissected tissues was weighed to the nearest gram. Carcass dressing percentage was determined from the live weight (weighed at the farm after fasting overnight with free access to drinking water) and the hot carcass weight.

Meat quality measurements

The samples were removed from the loin at the tenth rib and were placed in vacuum bags and frozen for meat quality analysis. pH was measured using a pH star (Osaka, Japan) at 45 min and 24 h postmortem on the loin according to the procedure described by Verónica et al. (2009). The electrode was calibrated with pH 4.6 and 7.0 buffers equilibrated at 35°C for the measurements of the warm carcass after 45 min and equilibrated at 4°C for the measurements at 24 h. Color parameters were determined using a Minolta CR-300 colorimeter (Minolta Camera, Osaka, Japan) with an illuminant D65, a 0° standard observer, and a 2.5-cm port/viewing area according to the procedure described by Miao et al. (2009). Drip loss was defined as the weight loss of a meat sample (50 g) that was placed on a flat plastic grid and wrapped in foil after a storage time of 24 h in a refrigerator (4°C) (Miao et al., 2009). The analysis of intramuscular fat (IMF) content was measured according to the AOAC (1990) procedures. Muscle fiber area was determined using the procedure described by Ginté and Vigilijus (2008).

Statistical analyses

Statistical analysis was performed using ANOVA of the SAS System for Windows version 8.0 (SAS Institute Inc., Cary, NC 27513, USA) in order to determine the differences in the carcass and meat quality traits among different crossbreeds. The Duncan test was applied to compare the mean values of the crossbreeds. Differences were considered to be significantly for $P \leq 0.05$.

RESULTS AND DISCUSSION

Carcass traits

Carcass traits of the various crossbreeds are shown in Table 1. There were large differences among the crossbreeds. DLY and PIC had heavier live weights (93.39 and 96.33 kg, respectively, $P < 0.01$), higher dressing percentages (80.65 and 79.39%, respectively, $P < 0.05$), thinner back fats (1.78 and 1.67 cm, respectively, $P < 0.001$), larger loin areas (42.69 and 43.91 cm^2, respectively, $P < 0.001$), more ham and breech (35.65 and 36.23%, respectively, $P < 0.05$), higher percentages of lean carcass weight (65.78 and 66.40%, respectively, $P < 0.001$), and lower levels of carcass fat and skin (21.17 and 20.17%, respectively, $P < 0.001$) compared with LM and DLM. In contrast, LM showed the lightest live weight (70.29 kg), the thickest back fat (3.54 cm), the smallest loin area (24.12 cm^2), the least ham and breech (26.53%), the lowest percentage of lean carcass weight (46.82%), and the highest level of carcass fat and skin (40.40%) among all crossbreeds investigated. There was no significant difference in carcass bone percentage among the crossbreeds. These results indicate that the native crossbreeds LM and DLM have higher capacities for depositing lipids, resulting in higher subcutaneous fat percentages and lower lean meat percentages compared with foreign crossbreeds DLY and PIC. The results also indicated that carcass traits are improved by decreasing the percentage of Meishan pig genetic contribution from 1/2 (LM) to 1/4 (DLM) in the crossbreeding system.

Table 1. Carcass traits in various crossbreeds.

	LM (N = 20)		DLM (N = 20)		DLY (N = 40)		PIC (N = 40)		P
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
Live weight (kg)	70.29[c]	5.48	85.76[b]	4.66	93.39[a]	6.38	96.33[a]	7.97	**
Dressing percentage (%)	71.68[b]	2.78	72.45[b]	1.92	80.65[a]	4.32	79.39[a]	3.67	*
Average backfat thickness (cm)	3.54[a]	0.37	2.73[b]	0.31	1.78[c]	0.21	1.67[c]	0.18	***
Loin area (cm^2)	24.12[c]	3.07	28.41[b]	2.91	42.69[a]	3.79	43.91[a]	4.05	***
Carcass lean (%)	46.82[c]	3.66	56.65[b]	1.27	65.78[a]	2.45	66.40[a]	2.12	***
Ham and breech (%)	26.53[c]	1.03	30.78[b]	1.96	35.65[a]	1.78	36.23[a]	2.03	*
Carcass fat and skin (%)	40.40[a]	5.20	30.56[b]	5.18	21.17[c]	3.28	20.17[c]	2.79	***
Carcass bone (%)	12.80	1.90	12.79	1.93	13.05	0.98	13.43	0.79	ns

LM = Landrace x Meishan crossbreed. DLM = Duroc x (Landrace x Meishan) crossbreed. DLY = Duroc x (Landrace x Yorkshire) crossbreed. PIC = foreign five-way crossbreed (Pig Improvement Co., Ltd.). Crossbreeds with different superscript letters for a trait differ significantly. ns = not significantly different ($P > 0.05$). *Significant at the 5% level. **Significant at the 1% level. ***Significant at the 0.1% level. SD = standard deviation.

Similar results have been previously reported. Legault et al. (1985) compared purebred Pietrain, Meishan x Pietrain, and Jiaxing Black x Pietrain lines and found heavier loins, legs, blades, and less back fats in Pietrain. Lan et al. (1993) also found that the pure Yorkshires had higher carcass weights, longissimus muscle areas, trimmed and boneless ham and loin weights, and boneless picnic weights than pure Meishan; further, the crossbred pigs from Yorkshire x Meishan and Meishan x Yorkshire were intermediate between Yorkshire and Meishan. Gispert et al. (2007) found that pure Meishan pigs had lighter carcass weights, lower lean meat percentages, and higher subcutaneous fat percentages compared with Landrace, Large White, Duroc, and Pietrain pigs. Young (1998) found few significant differences in carcass traits between pigs of 7/8 White Composite, 1/8 Duroc, 1/8 Meishan, 1/8 Fengjing, and 1/8 Minzhu pigs when using a constant carcass weight, although Duroc crosses were generally superior. There were few significant differences among 1/4 crosses of these breeds when carcass traits were compared at a constant carcass weight (Young, 1995). Differences among 1/4 breed types were significant for fat thickness at the first rib and tenth rib, loin area, untrimmed ham, trimmed ham, untrimmed picnic, trimmed picnic, and leaf fat (Young, 1995). In most cases, the significant effects resulted from differences between only two breed types (Young, 1995). Although the differences are smaller and often not significant, the differences among 1/8 and 1/4 crosses of these breeds generally agree with the differences reported by Young (1992, 1995) for pigs sired by Duroc, Meishan, Fengjing, and Minzhu boars. However, Cesar et al. (2010) compared carcass traits among pigs from line A (1/8 Meishan, 1/8 Fengjing, 1/8 Jiaxing) and line B (no Chinese breeds) and did not find similar results, since carcass lean percentage was significantly higher and back-fat thickness was significantly lower in line A compared to line B. These results may have resulted from the fact that line A had only 1/8 Chinese genetic composition. In the present study, the two native crossbreeds had poor carcass traits, because LM and DLM had 1/2 and 1/4 Meishan pig genetic contribution, respectively. These results indicate that reducing the degree of Meishan pig genetic contribution to 1/8 or 1/16 in a crossbreeding system will improve carcass traits.

Meat quality traits

Meat quality traits of the various crossbreeds are shown in Table 2. PIC pigs had the lowest pH_1 (5.82, $P < 0.01$) and pH_2 (5.63, $P < 0.01$) of all crossbreeds. pH was a major contributor to meat quality, which affects the technological quality of pork as well as the eating quality of pork (van Laack et al., 1994; van der Wal et al., 1995). Sellier (1998) reported that three distinct pH-related abnormalities are often cited: 1) pale, soft, exudative (PSE) meat, which is associated with pH_1 values lower than 5.9 depending on the muscle, 2) dark, firm, dry (DFD) meat, which is associated with pH_2 values higher than 6.2, and 3) "acid meat" condition, which is associated with pH_2 values lower than 5.4-5.5. In this study, pH_1 (6.01-6.18) and pH_2 (5.84-5.92) were within normal ranges for LM, DLM and DLY, and the meat had no characteristics of PSE, DFD, or "acid meat". The reason for higher pH in the three crossbreeds may be that the Chinese native breed and Duroc have higher pH levels. Indeed, similar results have been previously reported (Oliver et al., 1994; Latorre et al., 2003a; Jiang et al., 2011, 2012). Interestingly, pH_1 and pH_2 of PIC were very low at only 5.82 and 5.63, respectively. The lower pH may have resulted from Pietrain pig blood in the crossbreeding system of the PIC pig. To some extent, PIC appeared to have characteristics of PSE meat.

Table 2. Meat quality traits of loin in various crossbreeds.

	LM (N = 20)		DLM (N = 20)		DLY (N = 40)		PIC (N = 40)		P
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	
pH_1	6.18^a	0.09	6.01^b	0.17	6.08^{ab}	0.24	5.82^c	0.26	**
pH_2	5.92^a	0.19	5.84^a	0.23	5.92^a	0.32	5.63^b	0.07	**
Minolta L_1	45.27	2.41	44.03	2.41	43.53	2.56	45.75	3.70	ns
Minolta L_2	47.32	3.97	47.02	4.01	45.51	3.78	47.25	3.95	ns
IMF (%)	5.02^a	1.02	2.52^b	0.70	2.32^b	0.90	1.35^c	0.42	***
Drip loss (%)	2.16^c	0.78	2.23^{bc}	0.78	2.50^b	0.92	2.89^a	0.65	**
Fiber area (μm²)	3126.45^c	671.35	3554.23^b	609.61	4416.23^a	924.48	4217.38^a	786.56	**

LM = Landrace x Meishan crossbreed. DLM = Duroc x (Landrace x Meishan) crossbreed. DLY = Duroc x (Landrace x Yorkshire) crossbreed. PIC = foreign five-way crossbreed (Pig Improvement Co., Ltd.). pH_1, Minolta L_1 (at 45 min post-mortem); pH_2, Minolta L_2 (at 24 h post-mortem). Crossbreeds with different superscript letters for a trait differ significantly. ns = not significantly different ($P > 0.05$). **Significant at the 1% level. ***Significant at the 0.1% level. SD = standard deviation.

None of the Minolta L values was significantly influenced by crossbreeding. The present results corroborate those of previous reports (Lan et al., 1993; Young, 1992, 1998; Cesar et al., 2010), which found that Chinese pigs had no effect on meat color. However, some studies have shown that Chinese pig meat tended to be darker than that of foreign breeds (Yong, 1995; Miao et al., 2009; Jiang et al., 2011, 2012). According to the meat color standards of NPPC (2000), a color score of 3-5 or Minolta L value of 37-49 is considered to be good. In this study, the range of Minolta L values in the crossbreeds was 43.53-47.32, which is within the normal range and indicates normal meat color in the crossbreeds.

LM had the lowest drip loss (2.16%, $P < 0.01$), while PIC had the highest drip loss (2.89%, $P < 0.01$). Water is the major constituent of meat, representing approximately 75% of the meat weight. Water content is an essential quality parameter both for industry and for the consumer. High water holding capacity (WHC) values are advantageous in processed meats for the industry and for the meat's appearance to the consumer (den Hertog-Meischke et al., 1997). The main factors that affected WHC, and thus drip loss, were: genotype (HAL and RN genes), pre-slaughter management, and stunning methods (Claeys et al., 2001; Schäfer et al., 2002). According to den Hertog-Meischke et al. (1997), another important feature that affected WHC was the predominant type of fiber in the muscle. Muscles with more glycolytic fibers, also called white muscle fibers (fast contraction, type II A, anaerobic), had a lower WHC, a faster drop in pH after death (Lawrie, 2005), and a lower final pH. In this study, PIC pigs showed the highest drip loss, which could result from their lower pH levels.

The highest IMF content (5.02%) was observed in the LM crossbreed, while PIC had only 1.35% IMF content. IMF content is related to organoleptic characteristics of pig meat and influences the quality of meat and meat products (Wood et al., 1988). Generally, fat is an important holder of flavor. Consequently, IMF content influences tenderness, juiciness, and flavor of pig meat. Meat with a low fat content is insipid, stringy, and dry. An IMF content of 2.5% was suggested to be optimal for eating quality (Bejerholm and Barton-Gade, 1986; DeVol et al., 1988). However, because of the selection for high lean meat content, the average IMF content of pigs has decreased below this level. The Chinese pig had high IMF contents, which could increase IMF content in crossbreeds (Jiang et al., 2011, 2012). Meat from DLY and DLM had high intramuscular fat levels, a result similar to those of other studies (Barton-Gade, 1987; Edwards et al., 1992; Oliver et al., 1994; Latorre et al., 2003a) due to the higher percentage of fat of Duroc compared to other lean breeds. The continuing emphasis on selecting and producing pigs with a lower subcutaneous fat content may have contributed to the lowest level of IMF in PIC. Therefore, improving IMF content is a new objective for pig genetics and breeding. In this study, crossbreeds of LM, DLM, and DLY had higher IMF content, which can meet current demands for improved taste quality in niche products.

The fiber areas of LM and DLM were smaller than those of DLY and PIC, a result similar to that of a previous study (Lan et al., 1993), which reported that Meishan pigs had a smaller fiber area than Yorkshire pigs. Jiang et al. (2011, 2012) also found that pure Dahe and Yanan pigs had smaller fiber areas than crossbreeds. Muscle fiber area is an important factor affecting numerous pre- and post-mortem biochemical processes and thus meat quality (Klosowska and Fiedler, 2003). Pork muscle fiber area influences meat quality, and pork with high muscle fiber area has high levels of shear force, drip loss, and cooking loss (Ginté and Vigilijus, 2008). These results may help explain why LM and DLM pigs had higher water holding capacities, suggesting a contribution of smaller fiber areas.

CONCLUSION

The four crossbreeds in this study differed in carcass and meat quality traits. DLY and PIC had higher dressing percentages, larger loin areas, and greater percentages of lean carcass weight than LM and DLM. In contrast, LM showed the lowest live weight, thickest back fat, and lowest percentage of lean carcass weight among the crossbreeds. Among meat quality parameters, LM had the highest IMF and smallest fiber area. However, PIC showed the lowest pH_1 and pH_2 values, the highest drip loss, and the lowest IMF. These results indicated that LM and DLM pigs had good meat quality traits but poorer carcass traits than DLY and PIC; DLY had good carcass and meat quality traits; PIC had good carcass traits, lower IMF and pH and higher drip loss.

IMPLICATIONS

In this study, we investigated carcass and meat quality traits among representative crossbreeds used in a Chinese commercial pig population. The results showed that LM (1/2 Meishan) and DLM (1/4 Meishan) had good meat quality traits but poorer carcass traits than the imported modern crossbreeds, despite the better carcass traits found in DLM. The results indicate that reducing the percentage of Chinese native pig genetic composition in the crossbreeding system may improve carcass and meat quality traits. Nevertheless, it may be appropriate to preserve 1/8 or 1/16 native Chinese pig genetic composition in a commercial crossbreeding system. The imported modern crossbreeds, DLY and PIC, had good carcass traits, but PIC showed lower IMF and pH and a higher drip loss. Therefore, when choosing imported modern crossbreeds, it is important to recognize that meat quality traits depend on the crossbreeds.

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