

Effects of Breed and Nutritional Level on Growth Performance, Carcass Traits, and Meat Quality in Pigs Postprint

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Abstract

This experiment aimed to investigate the effects of breed and nutrient level on growth performance, carcass traits, and meat quality in pigs. Twelve pairs of Gaopo pigs and “Duroc × Landrace × Taoyuan” three-way crossbred pigs (DLT) with initial body weight of (61.16 ± 4.13) kg were selected, randomly divided into 4 treatments, and fed complete diets with different nutrient levels [NRC (2012), Chinese Feeding Standard for Swine (2004)]. The experimental pigs were slaughtered when their average body weight reached 90 kg. The results showed that DLT had significantly higher loin eye area than Gaopo pigs ($P < 0.05$), while intramuscular fat content, average backfat thickness, meat color lightness (L) at 24 h, and yellowness (b) at 24 h were significantly lower than those of Gaopo pigs ($P < 0.05$); feeding diets with high nutrient levels significantly reduced the feed conversion ratio of pigs ($P < 0.05$); increased dietary nutrient level significantly improved average daily gain, average daily feed intake, carcass length, and meat color redness (a) at 24 h in Gaopo pigs ($P < 0.05$), and significantly decreased meat color L at 24 h, drip loss, and the relative mRNA expression levels of sterol regulatory element binding protein-1c and hormone-sensitive lipase in the longissimus dorsi muscle ($P < 0.05$); increased dietary nutrient level significantly decreased meat color a^* at 45 min and a^* at 24 h in DLT ($P < 0.05$). In conclusion, under the conditions of this experiment, breed and nutrient level had significant effects on growth performance, carcass traits, and meat quality in pigs; DLT had superior carcass traits compared with Gaopo pigs, while the opposite was true for meat quality. Increased dietary nutrient level significantly improved carcass traits in DLT and meat quality in Gaopo pigs, with certain improvements in growth performance.

Full Text

Effects of Breed and Nutrient Level on Growth Performance, Carcass Traits and Meat Quality of Pigs

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Abstract

This experiment was conducted to investigate the effects of breed and nutrient level on growth performance, carcass traits, and meat quality in pigs. Twelve pairs of Gaopo pigs and “Duroc × Landrace × Taihu” crossbred pigs (DLT) with an initial body weight of (61.16 ± 4.13) kg were randomly assigned to four treatments and fed complete diets with different nutrient levels [NRC (2012) and Chinese Feeding Standard of Swine (2004)]. Pigs were slaughtered when they reached an average body weight of 90 kg. The results showed that DLT had significantly greater loin-eye area ($P < 0.05$) but lower intramuscular fat content, average backfat thickness, and meat color parameters L and b compared with Gaopo pigs ($P < 0.05$). Feeding high-nutrient-level diets significantly reduced feed-to-gain ratio ($P < 0.05$). Elevated dietary nutrient levels significantly increased average daily gain, average daily feed intake, carcass length, and meat color a in Gaopo pigs ($P < 0.05$), while significantly decreasing meat color L , drip loss, and relative mRNA expression of sterol regulatory element binding protein-1c (SREBP-1c) and hormone-sensitive lipase (HSL) in the longissimus dorsi muscle ($P < 0.05$). In DLT, increased nutrient levels significantly reduced meat color a and a ($P < 0.05$). In conclusion, breed and nutrient level significantly affected growth performance, carcass traits, and meat quality under the conditions of this experiment. DLT exhibited superior carcass traits but inferior meat quality compared with Gaopo pigs. Elevated dietary nutrient levels significantly improved carcass traits in DLT and meat quality in Gaopo pigs, while also providing some improvement in growth performance.

Keywords: breed; nutrient level; growth performance; carcass traits; meat quality

Gaopo pig is an important local breed in Guizhou Province, characterized by its tolerance to roughage, superior meat quality, early sexual maturity, and strong stress resistance. The “Duroc × Landrace × Taihu” crossbred pig (DLT) combines the high reproductive performance of Chinese indigenous breeds with adaptability to local socioeconomic conditions. Although numerous studies have

investigated the nutrient requirements of local pig breeds [1-2], the specific nutrient requirements for Gaopo pigs and DLT remain unclear. Therefore, exploring the effects of nutrient levels on growth performance, carcass traits, and meat quality in these breeds holds significant practical importance.

Previous research has demonstrated that different pig breeds exhibit significant variation in intramuscular fat, muscle pH, marbling, meat color, and water-holding capacity, indicating that breed significantly influences meat quality [3-5]. Dietary energy supply directly affects ultimate muscle pH, shear force, water-holding capacity, and meat color [6-7], while increased dietary protein level reduces backfat thickness and increases lean meat percentage [8]. Dietary supplementation with vitamins and minerals can significantly improve muscle quality [9-11]. These findings indicate that different nutrient levels exert distinct effects on meat quality. Due to genetic background differences, meat quality should vary between Gaopo pigs and DLT, which contains foreign genetic lines. Moreover, the impact of nutrient levels on meat quality may differ between these two breeds. Therefore, this study selected Gaopo pigs and DLT with similar body sizes as experimental subjects, feeding them complete diets formulated according to two different nutritional standards to investigate the effects of nutrient levels on growth performance, carcass traits, and meat quality. The objective was to reveal differences in meat quality between Gaopo pigs and DLT and their compatibility with the two nutrient levels, providing reference for dietary formulation in the production of these breeds.

1.1 Experimental Design and Animals

A 2×2 factorial design was employed with two main effects: breed (Gaopo pig vs. DLT) and nutrient level [NRC (2012) vs. Chinese Feeding Standard of Swine (2004)]. Twelve DLT and twelve Gaopo pigs with an initial body weight of (61.16 ± 4.13) kg were allocated to four treatments: DLT with Chinese standard (DLT+C), DLT with NRC standard (DLT+N), Gaopo pig with Chinese standard (Gaopo+C), and Gaopo pig with NRC standard (Gaopo+N). Each treatment consisted of six pigs.

1.2 Experimental Diets

The experimental diets were corn-soybean meal-based and formulated according to the nutrient requirements specified in NRC (2012) and Chinese Feeding Standard of Swine (2004) for the corresponding growth stage. Diet composition and nutrient levels are presented in Table 1 .

1.3 Animal Management

The experiment was conducted at the teaching and research farm of the Institute of Animal Nutrition, Sichuan Agricultural University. Pigs were housed individually in pens. After a 5-day adaptation period, the formal experiment began. Pigs were fed three times daily (08:30, 13:30, and 18:30) with small

amounts added frequently to ensure slight feed remaining in the trough. Pigs had ad libitum access to water, and pen temperature was maintained at 18–20 °C.

1.4 Slaughter and Tissue Sampling

Slaughter was conducted in batches. When the average body weight of experimental pigs reached 90 kg, the five heaviest pigs were selected for slaughter. The left carcass (with leaf lard and kidneys retained) was immediately separated for carcass trait measurements. The longissimus dorsi muscle was rapidly sampled at the thoracolumbar junction; one portion was used for measuring meat color, marbling, and shear force. The longissimus dorsi muscle from the 1st–2nd thoracic vertebrae was sampled for muscle pH measurement, with sample width and thickness both exceeding 3 cm. The longissimus dorsi muscle from the 3rd–4th thoracic vertebrae was sampled, with the muscle membrane removed, for drip loss determination.

1.5.1 Growth Performance

Residual feed was recorded daily, and feed intake was documented. Pigs were weighed weekly at 08:00 after overnight fasting. Average daily feed intake (ADFI) = total feed intake during the experimental period / number of days; Average daily gain (ADG) = total weight gain during the experimental period / number of days; Feed-to-gain ratio (F/G) = ADFI / ADG.

1.5.2 Carcass Traits

Carcass composition measurements and calculations followed the methods described in *Swine Production* [12].

1.5.2.1 Carcass Weight

Carcass weight was defined as the weight of the remaining carcass after removal of head, feet, tail, and internal organs, following dehairing and bloodletting.

1.5.2.2 Carcass Length

Carcass length was measured from the junction of the first rib and sternum to the anterior edge of the pubic symphysis (left half carcass).

1.5.2.3 Dressing Percentage

Dressing percentage was calculated as carcass weight divided by pre-slaughter live weight, expressed as a percentage.

1.5.2.4 Average Backfat Thickness

Backfat thickness was measured at the thickest point of the shoulder, the thoracolumbar junction, and the lumbosacral junction using a vernier caliper. The average of these three measurements was recorded as average backfat thickness.

1.5.2.5 Loin-Eye Area

The height and width of the longissimus dorsi muscle cross-section between the

12th-13th ribs were measured using a vernier caliper. Loin-eye area (cm²) = loin-eye height (cm) × loin-eye width (cm) × 0.7.

1.5.3 Meat Quality Measurements

Sample collection was performed according to NY/T 1333-2007 *Method for Determination of Meat Quality in Livestock and Poultry* [13] and GB/T 5009.6-2003 [14].

1.5.3.1 Muscle pH

Muscle pH was measured directly in samples at 45 min and 24 h post-slaughter using a portable pH meter (OPTO-STAR, R. Matthaus, Germany).

1.5.3.2 Meat Color

Meat color parameters L* (lightness), a* (redness), and b* (yellowness) of the longissimus dorsi muscle were measured directly at 45 min and 24 h post-slaughter using a colorimeter (CR-300, Minolta, Japan).

1.5.3.3 Drip Loss

Fresh muscle tissue was trimmed into blocks measuring 5 cm × 3 cm × 2 cm and weighed (W). Samples were suspended with wire, sealed in air-filled plastic bags, and hung at 4 °C for 24 h. After removal from the bags, samples were weighed again (W'). Drip loss (%) = [(W - W')/W] × 100.

1.5.3.4 Marbling Score

Muscle samples stored for 24 h were cut, and the fresh surface was scored against the marbling score chart (NPPC, 1991). Scores ranged from 1 to 5, with 0.5-point increments allowed.

1.5.3.5 Intramuscular Fat

A 20 g muscle sample was freeze-dried to determine dry matter content. The dried sample was ground through a 40-mesh sieve, and intramuscular fat content was determined according to GB/T 5009.6-2003.

1.5.3.6 Shear Force

Longissimus dorsi samples were stored at 4 °C for 72 h. A rectangular block (2.5 cm thick, 7 cm long) was placed in a cooking bag, air was expelled, and the bag was sealed and heated in an 80 °C water bath until the core temperature reached 70 °C. After cooling to room temperature, samples were cored parallel to the muscle fiber direction and shear force was measured using a tenderness meter. Nine replicates were measured per sample, and the average value was recorded.

1.5.4 Relative Expression of Lipid Metabolism-Related Genes in Longissimus Dorsi Muscle

1.5.4.1 Total RNA Extraction

Total RNA was extracted from longissimus dorsi muscle samples stored in an ultra-low temperature freezer using the RNAiso Reagent kit (TaKaRa, Dalian,

China) according to the manufacturer's instructions. After RNA precipitation, the pellet was dissolved in diethyl pyrocarbonate (DEPC)-treated water, and RNA concentration and integrity were assessed.

1.5.4.2 Primer Design

Primers were designed based on GenBank-published sequences for sterol regulatory element binding protein-1c (SREBP-1c), hormone-sensitive lipase (HSL), fatty acid synthase (FAS), and 18S-rRNA genes. Primer specificity was verified, and 18S-rRNA served as the internal reference. Primers were synthesized by Invitrogen. Primer sequences for target genes and 18S-rRNA for real-time quantitative PCR are listed in Table 2.

1.5.4.3 cDNA Synthesis

cDNA was synthesized using the SYBR Prime Script™ RT-PCR kit (TaKaRa, Dalian, China) following the manufacturer's protocol.

1.5.4.4 Standard Curve Preparation

Standard curves for target genes and 18S-rRNA were generated using six points with three replicates each. After reverse transcription, cDNA solutions were serially diluted (10, 10, 10, 10, 10¹, and 10¹¹) using EASY Dilution. One microliter of each dilution was used for real-time quantitative PCR.

1.5.4.5 Real-Time Quantitative PCR

SYBR Premix Ex Taq™ (TaKaRa, Dalian, China) was used for PCR amplification of internal reference and target genes. The 10 µL reaction mixture contained 5 µL SYBR Premix Ex Taq™ (2×), 1 µL each of forward and reverse primers (4 µmol/L), 2 µL DEPC-treated water, and 1 µL cDNA (10 ng). Cycling conditions were: 95 °C for 10 s, followed by 40 cycles of 95 °C for 5 s and annealing for 25 s (annealing temperatures listed in Table 2). After amplification, melting curve analysis was performed from 65 °C to 95 °C, reading the plate every 0.5 °C for 0.5 s with continuous fluorescence detection.

1.6 Statistical Analysis

Relative mRNA expression levels of SREBP-1c, HSL, and FAS were calculated using the $2^{-\Delta\Delta Ct}$ method [15]. Data were processed using Excel 2010 and analyzed using the General Linear Model (GLM) procedure in SAS 9.0 software for two-way analysis. Duncan's multiple range test was used for post-hoc comparisons. Results are expressed as means and standard errors. Differences were considered significant at $P < 0.05$.

2.1 Effects of Breed and Nutrient Level on Growth Performance

As shown in Table 3, increased dietary nutrient level significantly reduced feed-to-gain ratio (F/G) in pigs ($P < 0.05$). A significant interaction between nutrient level and breed was observed for average daily gain (ADG) and average daily feed intake (ADFI) ($P < 0.05$). Increasing nutrient level improved ADG and

ADFI only in Gaopo pigs ($P < 0.05$) but had no significant effect on ADG and ADFI in DLT ($P > 0.05$).

2.2 Effects of Breed and Nutrient Level on Carcass Traits

The effects of breed and nutrient level on carcass traits are presented in Table 4. DLT exhibited significantly greater loin-eye area and lower average backfat thickness compared with Gaopo pigs ($P < 0.05$). A significant interaction between nutrient level and breed was observed for carcass length ($P < 0.05$). As nutrient level increased, carcass length increased significantly in Gaopo pigs ($P < 0.05$) but remained unchanged in DLT ($P > 0.05$). Neither breed nor nutrient level significantly affected carcass weight or dressing percentage ($P > 0.05$).

2.3 Effects of Breed and Nutrient Level on Meat Quality

As shown in Table 5, meat quality was affected by breed and nutrient level, particularly in drip loss and meat color parameters a^* , a , L^* , and b^* ($P < 0.05$). Gaopo pigs exhibited significantly higher L^* and b^* values than DLT ($P < 0.05$), with a tendency for higher L^* ($0.05 < P < 0.10$). A significant interaction between nutrient level and breed was observed for a^* ($P < 0.05$). Elevated nutrient level significantly increased a^* in Gaopo pigs ($P < 0.05$) while significantly decreasing a^* and a in DLT ($P < 0.05$). Nutrient level also significantly affected L^* and drip loss ($P < 0.05$). No significant effects of breed or nutrient level were observed for b^* , pH, or shear force ($P > 0.05$).

2.4 Effects of Breed and Nutrient Level on Intramuscular Fat Content

The effects of breed and nutrient level on intramuscular fat content in the longissimus dorsi muscle are shown in Figure 1 [Figure 1: see original paper]. Intramuscular fat content differed between breeds, with Gaopo pigs showing higher levels than DLT. Nutrient level had no significant effect on intramuscular fat content ($P > 0.05$).

2.5 Effects of Breed and Nutrient Level on Relative Expression of Lipid Metabolism Genes

The effects of breed and nutrient level on relative expression of lipid metabolism-related genes in the longissimus dorsi muscle are presented in Figure 2 [Figure 2: see original paper]. Elevated nutrient level significantly down-regulated relative mRNA expression of SREBP-1c and HSL only in Gaopo pigs ($P < 0.05$) but had no significant effect on SREBP-1c and HSL expression in DLT ($P > 0.05$). Neither breed nor nutrient level significantly affected FAS mRNA expression ($P > 0.05$).

Discussion

Nutrient requirements vary among pigs due to differences in breed, body weight, and rearing conditions. Both insufficient and excessive dietary nutrient levels can alter growth performance. Gaopo pigs exhibit good carcass traits and superior meat quality but have low lean meat percentage and slow growth. Improving their growth performance through nutritional modulation holds significant production value. Compared with NRC (2012), the Chinese Feeding Standard of Swine (2004) represents a lower-energy, lower-protein dietary standard. Kim et al. [16] reported that increasing dietary energy level significantly reduced F/G. In this study, feeding Gaopo pigs the NRC (2012) diet increased ADG and reduced F/G, indicating that elevated nutrient levels can improve growth rate and feed conversion efficiency in this breed. Increased dietary energy level can elevate blood leptin concentration [17], which suppresses appetite and reduces energy intake by inhibiting neuropeptide Y expression and secretion [18].

Carcass traits refer to carcass weight and composition, primarily including carcass weight, average backfat thickness, loin-eye area, and dressing percentage. In this study, DLT showed significantly greater carcass length and loin-eye area but lower average backfat thickness than Gaopo pigs, demonstrating significant breed differences in carcass traits, consistent with findings by Chu et al. [19]. Numerous studies have shown that increased dietary protein level promotes protein deposition and increases loin-eye area [8,20]. In this study, DLT fed high-protein diets showed increased loin-eye area, whereas Gaopo pigs fed high-protein diets exhibited reduced loin-eye area. Under the NRC (2012) nutrient level, Gaopo pigs showed significantly increased ADG but no change in carcass weight. This may be because pigs were slaughtered at consistent body weights but different ages, resulting in different muscle development status that affected carcass traits. Therefore, it is normal that the increased ADG in Gaopo pigs under NRC (2012) was not reflected in carcass weight. Yan et al. [21] also reported that slaughter age can affect carcass weight.

Breed is the primary determinant of pork quality, with significant variation observed among different breeds and lines. Studies have shown significant breed differences in marbling, pH, meat color, and drip loss [22]. The present results indicate that when fed the same diet, Gaopo pigs exhibited slower pH decline in the longissimus dorsi muscle from 45 min to 24 h post-slaughter compared with DLT. The extent of pH change reflects meat tenderness [23], suggesting that Gaopo pigs have better tenderness and are less prone to pale, soft, exudative (PSE) meat. Dietary nutrient level significantly affects pork quality; appropriate energy and protein levels not only influence growth performance, carcass traits, and feed costs but also affect meat flavor, tenderness, and juiciness, thereby influencing consumer sensory quality. Ou et al. [24] found that dietary nutrient level significantly affected meat color, drip loss, and marbling. In this study, feeding high-nutrient-level diets to Gaopo pigs increased meat color a^* and reduced drip loss, with a tendency to improve marbling score. Therefore, high-nutrient-level diets can improve the sensory quality of Gaopo pig meat.

Intramuscular fat is rich in phospholipids, which are important precursors of volatile flavor compounds in meat. Studies have shown that dietary energy level does not significantly affect intramuscular fat content, with primary influencing factors being breed, slaughter weight, and muscle location [25]. In this study, Gaopo pigs had significantly higher intramuscular fat content in the longissimus dorsi muscle than DLT, while nutrient level showed no significant effect. This suggests that breed is the main factor affecting intramuscular fat content, and that excess energy beyond a certain level is dissipated as heat [26-27]. Huang et al. [28] investigated the effects of NRC (1998) and Wujin pig diets on lipid catabolism-related gene expression in Wujin pig adipose tissue and found higher HSL mRNA expression in the Wujin pig diet group compared with the NRC (1998) group. In this study, elevated nutrient level significantly down-regulated SREBP-1c and HSL mRNA expression in Gaopo pigs. SREBP-1c is a key transcription factor regulating lipid synthesis [29] that activates genes encoding enzymes for fatty acid biosynthesis [30]. FAS is the key enzyme for de novo fatty acid synthesis in animals and the main rate-limiting enzyme for maximal fatty acid regeneration in body tissues [31]. These results suggest that under high nutrient levels, Gaopo pigs inhibit adipose tissue lipolysis and increase fat deposition by down-regulating expression of lipid catabolism-related genes.

In summary, under the conditions of this experiment, breed and nutrient level significantly affected growth performance, carcass traits, and meat quality in pigs. DLT demonstrated superior carcass traits but inferior meat quality compared with Gaopo pigs. Elevated dietary nutrient levels significantly improved carcass traits in DLT and meat quality in Gaopo pigs, while also providing some improvement in growth performance.

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