Comparison of growth performance, chemical composition, and functional amino acids composition of hybrid wild boars under different crossing systems

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Abstract

The objective of this experiment was to evaluate the growth performance, chemical composition, and functional amino acids (FAA) composition of two crossing systems between wild boars and different domesticated pig breeds. Forty castrated male pigs at 60 days of age from 3 breeds including Wild boar (W), Bamei (B) and Yorkshire (Y) and their crossing systems Wild boar × Bamei (W × B) and Wild boar × Yorkshire (W × Y) were assigned into five groups, respectively. After 100 days of feeding, the growth performance, chemical composition and amino acids (AA) in longissimus muscle were analysed. The ADG (P<.01) in W was lower than other breeds (B and Y) and their crossing systems (W × B and W × Y) (P<.01). The content of intramuscular fat (IMF) was decreased (P<.01) in W when compared with other breeds (B and Y) and their crossing systems (W × B and W × Y) (P<.01). In terms of the levels of FAA, leucine in W was lower than those of the other breeds (B and Y) or their crossing systems (W × B and W × Y) (P<.01), whereas the levels of proline, cysteine, glutamate, total FAA, total AA, and total FAA/total AA was the highest in the Wild boar (P<.01). Herein, cross breeding with domesticated pigs was shown to be an effective method to improve the growth performance of wild boars, and the extent of improvement was breed dependent. Compared with domesticated pigs and cross-bred pigs, wild boars showed lower growth rate, but lower IMF and better FAA composition in longissimus muscle.

Introduction

Although the indigenous pig breeds in China are famous for their excellent meat quality and reproduction performance (Lee et al. 2012), the exploitation and development of indigenous pig breeds, especially in Qinghai-Tibetan Plateau, is just beginning in China. In fact, domestic pigs in China were probably domesticated from the subspecies of wild boars (Yang et al. 2011). Since wild boar evolve a series of excellent physiological characteristics, such as strongibs, narrow body, powerful lung and cardiac, disease resistance ability and good meat quality, there is a growing interest in improving the production of wild boar, such as poor reproduction performance, low feed conversion rate and intramuscular fat (IMF) (Marsico et al. 2010).

However, there is only limited evidence considering the improvement of growth performance and meat quality in wild boars. In commercial pig lines, it has been well demonstrated that crossing is a good way to improve carcass traits and meat quality (Cesar et al. 2010; Jiang et al. 2011). Based on the results of previous published studies, the hybrids between Chinese indigenous pigs and wild boars significantly increased its percent lean, meat quality, and nutritional value. Meanwhile, the hybrids between Western pigs and wild boars showed the hybrid vigour in growth performance (Marsico et al. 2010).

The meat quality was affected by multi-factors including the diet composition, environment, breed, genetic improvement, and amino acid composition (Franco et al. 2014; Sales et al. 2013). Functional amino acids (FAA) may be a vital role affecting the meat quality, nutrition, and health in pigs (Wu et al. 2009). During the past decades, FAA had been studied extensively, encompassing intracellular signalling pathways in various organisms from yeast to mammals (Kimball and Jefferson 2000) and the interaction among AA, protein synthesis, and signal transduction in organisms (Wu 2013). Based on the foregoing lines of compelling evidence from animal to human, some researchers had defined the new concept on FAA including arginine (Arg), leucine (Leu), glutamate (Glu), proline (Pro), cysteine (Cys), and tryptophan (Trp), which participate in and regulate some key metabolic pathways to improve health, survival, growth, development, lactation, and reproduction of the organisms (Wu 2009; Kim et al. 2011; Wu 2013). To date, few studies have been determined compositions and concentrations of FAA and AA in longissimus muscle in pigs (Okrouhla 2008; Jiang et al. 2011; Conde-Aguilera et al. 2014). In recent years, growing studies demonstrated that the AA composition of longissimus muscle could represent that in the whole body (Wang et al. 2013; Wu et al. 2013).
On account of these AA with such particular important biological functions in animal and human, the objective of this study was to investigate the growth performance, meat quality, and FAA composition of three breeds including W, B, and Y and their crossing systems W × B and W × Y, respectively.

Materials and methods

Experimental design, animals, diets, and management

The study was conducted in Xinhua farms at Linze city, western Gansu province of China. All experimental protocols were approved by the Animal Care Advisory Committee of Gansu Province and Southwest University for Nationalities.

According to three breeds W (8 pigs), B (8 pigs) and Y (8 pigs) and their cross combinations W × B, (8 pigs) and W × Y (8 pigs), a total of 40 castrated male piglets (ranging from 12.40 to 14.50 kg of body weight (BW)) at the age of 60 days were selected from Osmanthus Plateau Forest at Gansu district.

Pigs were fed diets formulated to meet NRC-recommended nutrient requirements (NRC 2012) and the ingredients and chemical composition of the basal diet are shown in Table 1.

The pigs had ad libitum access to the water and feed, and then remaining feed was weighed at 0800 h per day. Average daily feed intake and BW were recorded weekly to assess the feed to gain ratio (F/G) and average daily gain (ADG) (Wang et al. 2015). In addition, the signs of diarrhoea, sickness, and abnormal behaviour were also recorded daily (Wang et al. 2016).

The chemical composition of longissimus muscle was determined in accordance with previously described (Okrouhla et al. 2006). Briefly, moisture in longissimus muscle was determined in a 12 g sample that was ground and dried at the temperature of 105°C for 4 h 30 min till constant weight. The crude protein (CP) content was analysed using the method of Kjeldahl. IMF was detected by the gravimetric determination after extraction with petroleum ether-Soxhlet.

Slaughter surveys and sampling measure

On day 100, all pigs after 24 hours fasting were sacrificed in accordance with the standard procedures (Ma et al. 2004). The longissimus muscle at 10th rib from the left side of carcass was weighed using sealed vacuum bags, and were then stored at −20°C until analyses.

The analysis of FAA

The content of AA was determined using the following methods described by Lu et al. (2008). Briefly, the longissimus muscle samples were cut into slices and dried in a vacuum-freeze dryer, allowed to equilibrate with atmospheric moisture for 24 hours, and subsequently finely ground to pass a 60-mesh sieve. The AA content of samples was analysed using ion-exchange chromatography with an Automatic Amino Acid Analyzer (L-8800 Hitachi Automatic Amino Acid Analyzer, Tokyo, Japan) after hydrolysing with 6 N HCl at 110°C for 24 h. Meanwhile, cystine, tryptophan, and methionine were partly destroyed with acid hydrolysis, respectively. Furthermore, methionine and cystine were analysed after cold formic acid oxidation for 16 h before acid hydrolysis, respectively. However, tryptophan was determined after alkaline hydrolysis with 4 N NaOH for 22 h at 110°C.

Statistical analysis

Analyses of variance were performed on all the variables measured using one-way ANOVA procedure of the SAS Institute (SAS 2002). Analysis of variance was used to analyse growth performance, chemical composition, and the content of AA in longissimus muscle. The model of breed and cross was conducted on the main effect factor using the individual pig as the experimental unit. Differences were considered significant if \( P < .05 \).

Results

Growth performance

The effects of breeds and crossbreds on growth performance were shown in Table 2. During the experiment, the pigs were healthy, and the mortality was zero (data not shown). The ADG of W pigs was lower than B and Y pigs \( (P < .01) \). Meanwhile, the ADG was increased in cross combinations \( (W \times B \text{ and } W \times Y) \) pigs when compared with W pigs \( (P < .01) \).

Chemical compositions of longissimus muscle

The chemical composition (e.g. Moisture, IMF, and CP) of longissimus muscle in wild boar and other breeds were presented in Table 3. The range of the content of moisture, IMF and CP was

### Table 1. Composition of the diet provided to the experimental pigs.

| Ingredient | Content |
|------------|---------|
| Corn (8.00% CP) | 58.20 |
| Wheat bran (14.70% CP) | 15.00 |
| Wheat middling (15.00% CP) | 3.00 |
| Soybean meal (44.20% CP) | 10.00 |
| Rapeseed meal (36.00% CP) | 5.00 |
| DDGS (23.60% CP) | 2.00 |
| Barley malt sprouts (28.30% CP) | 3.00 |
| Fish meal (65.70% CP) | 1.00 |
| 1% Premixb | 1.00 |
| Calcium carbonate (38.00% Ca) | 0.60 |
| Dicalcium phosphate (21.00% P) | 0.90 |
| Sodium chloride (%) | 0.30 |
| Calculated composition | |
| Dry matter (DM, %) | 80.14 |
| Crude protein (CP, %) | 14.41 |
| Crude fat (EE, %) | 2.93 |
| Crude fibre (CF, %) | 3.65 |
| Ash (%) | 4.60 |
| Calcium (Ca, %) | 0.72 |
| Phosphorus (P, %) | 0.60 |
| Sodium chloride (NaCl, %) | 0.38 |
| Digestible energy (DE, MJ/kg) | 12.56 |

Note: DDGS = distillers dried grains with soluble

*The CP content of raw data was provided by Lanzhou Boya Feed Co., Ltd.

b1% premix provided the following per kilogram of the diet: Fe, 100.00 mg; Zn, 100.00 mg; Mn, 60.00 mg; Cu, 50.00 mg; Se, 0.37 mg; I, 0.55 mg; Vitamin A, 2,000 IU; Vitamin D₃, 200 IU; Vitamin E, 35.00 mg; Biotin, 0.05 mg; Folic acid, 0.30 mg; Nicotinic acid, 20.00 mg; Ca D-pantothenic acid, 20.00 mg; Vitamin B₁, 2.00 mg; Riboflavin, 2.50 mg; VitaminB₆, 1.00 mg; VitaminB₁₂, 0.01 mg; Choline chloride, 500.00 mg; Antioxidant, 30.00 mg; 10% Bacitracin zinc, 20.00 mg.
Table 2. The effect of breed and cross on productive traits of pigs (8 pigs/treatment).

| Items                  | Breeds                  | W     | B     | Y     | W×B   | W×Y   | SEM   | P-value |
|------------------------|-------------------------|-------|-------|-------|-------|-------|-------|---------|
| Feeding days (d)       | 100                     | 100   | 100   | 100   | 100   | 100   |       |         |
| Slaughter age (d)      | 161                     | 161   | 161   | 161   | 161   | 161   |       |         |
| Initial weight (kg)    | 12.40\textsuperscript{b}| 13.09\textsuperscript{ab} | 13.96\textsuperscript{a} | 13.63\textsuperscript{ab} | 14.50\textsuperscript{a} | 0.47  | *      |
| Final weight (kg)      | 47.57\textsuperscript{d} | 67.50\textsuperscript{b} | 88.74\textsuperscript{a} | 59.86\textsuperscript{c} | 65.20\textsuperscript{bc} | 2.11  | ***    |
| ADG (g/day)            | 402\textsuperscript{d}  | 544\textsuperscript{b}  | 748\textsuperscript{a}  | 480\textsuperscript{d}  | 563\textsuperscript{b}  | 13.78 | ***    |
| CP                     | 22.10\textsuperscript{ab} | 22.28\textsuperscript{a} | 20.78\textsuperscript{b} | 21.20\textsuperscript{ab} | 17.00\textsuperscript{a} | 0.12  | ***    |

Notes: W: Wild boar; B: Bamei; Y: Yorkshire; W × B: Wild boar × Bamei; W × Y: Wild boar × Yorkshire; ADG: average daily gain.
\textsuperscript{a,b,c,d}Means within a row with different superscripts indicate significant differences; ns at P > .05.
*Significant at the 5.00% level.
***Significant at the 0.10% level.

Table 3. The effects of breed and cross on chemical compositions in longissimus muscle of pigs (8 pigs/group).

| Items                  | Breeds                  | W     | B     | Y     | W×B   | W×Y   | SEM   | P-value |
|------------------------|-------------------------|-------|-------|-------|-------|-------|-------|---------|
| Moisture               | 72.38\textsuperscript{bc}| 70.10\textsuperscript{d} | 74.34\textsuperscript{a} | 72.38\textsuperscript{d} | 74.34\textsuperscript{a} | 0.43  | ***    |
| IMF                    | 3.01\textsuperscript{d}  | 6.34\textsuperscript{a}  | 4.36\textsuperscript{c}  | 4.76\textsuperscript{d}  | 3.57\textsuperscript{c}  | 0.15  | ***    |
| CP                     | 22.10\textsuperscript{bc} | 22.28\textsuperscript{a} | 20.78\textsuperscript{b} | 21.20\textsuperscript{bc} | 17.00\textsuperscript{a} | 0.12  | ***    |

Notes: W: Wild boar; B: Bamei; Y: Yorkshire; W × B: Wild boar × Bamei; W × Y: Wild boar × Yorkshire; IMF: intramuscular fat; CP: crude protein.
\textsuperscript{a,b,c,d}Means within a row with different superscripts indicate significant differences; ns at P > .05.
*Significant at the 5.00% level.
**Significant at the 1.00% level.
***Significant at the 0.10% level.

Table 4. The effects of breed and cross on the levels of AA in longissimus muscle (g/100 g Dried meat, %).

| Items                  | Breeds                  | W     | B     | Y     | W×B   | W×Y   | SEM   | P-value |
|------------------------|-------------------------|-------|-------|-------|-------|-------|-------|---------|
| Threonine              | 7.98\textsuperscript{a} | 7.58\textsuperscript{a} | 6.75\textsuperscript{b} | 7.79\textsuperscript{a} | 7.97\textsuperscript{a} | 0.23  | **     |
| Valine                 | 3.11                    | 3.30   | 3.08   | 3.56   | 3.20   | 0.12  | ns     |
| Methionine             | 2.23\textsuperscript{a} | 1.81\textsuperscript{b} | 1.83\textsuperscript{b} | 2.05\textsuperscript{ab} | 2.12\textsuperscript{b} | 0.10  | *      |
| Isoleucine             | 2.33\textsuperscript{b} | 3.41\textsuperscript{b} | 3.32\textsuperscript{b} | 3.36\textsuperscript{b} | 2.60\textsuperscript{b} | 0.14  | ***    |
| Phenylalanine          | 2.56\textsuperscript{c} | 3.37\textsuperscript{b} | 3.26\textsuperscript{c} | 2.93\textsuperscript{bc} | 2.56\textsuperscript{a} | 0.13  | ***    |
| Tyrosine               | 3.31                    | 3.50   | 3.32   | 3.48   | 3.27   | 0.13  | ns     |
| Histidine              | 5.04\textsuperscript{b} | 5.08\textsuperscript{b} | 5.04\textsuperscript{b} | 3.16\textsuperscript{bc} | 4.28\textsuperscript{b} | 0.11  | ***    |
| Aspartic acid          | 9.26\textsuperscript{a} | 7.19\textsuperscript{b} | 6.83\textsuperscript{d} | 7.29\textsuperscript{d} | 8.68\textsuperscript{dc} | 0.19  | ns     |
| Glucose                | 4.82                    | 5.00   | 4.85   | 4.42   | 4.69   | 0.14  | ns     |
| Serine                 | 4.78\textsuperscript{a} | 4.38\textsuperscript{b} | 4.31\textsuperscript{c} | 4.99\textsuperscript{a} | 4.47\textsuperscript{b} | 0.13  | **     |
| Tyrosine               | 3.35\textsuperscript{a} | 2.56\textsuperscript{d} | 2.10\textsuperscript{a} | 3.22\textsuperscript{d} | 3.41\textsuperscript{a} | 0.13  | ***    |

Notes: W: Wild boar; B: Bamei; Y: Yorkshire; W × B: Wild boar × Bamei; W × Y: Wild boar × Yorkshire; FAA: functional amino acids.
\textsuperscript{a,b,c,d}Means within a row with different superscripts indicate significant differences; ns at P > .05.
*Significant at the 5.00% level.
**Significant at the 1.00% level.
***Significant at the 0.10% level.

**Functional amino acid and AA**

The levels of AA in pigs were shown in Table 4, and the percentages of each FAA/total AA and total FAA/total AA were revealed in Figure 1. The levels of Arg and Trp had no significant differences in W pigs compared to other breeds (B and Y pigs) as well as their cross combinations (W × B and W × Y pigs) (P > .05). The levels of Pro, Cys, Glu, total FAA, total AA, and total FAA/total AA in W pigs were higher than other breeds (B and Y pigs) and their cross combinations (W × B and W × Y pigs) (P < .01). However, the levels of Leu in W pigs was lower than other breeds (B and Y pigs) and their cross combinations (W × B and W × Y pigs) (P < .01).

### Discussion

Although the meat of wild boar has a special flavour as a top grade palatable, it also has some disadvantages including poor growth performance and less IMF content (Marsico et al. 2010). Many efforts involved in improving the overall production performance of wild boar have been made to satisfy its increasing market demand in recent years (Zhang et al. 2015). Revealed in recent research, crossing wild boars with other breeds from domestic pigs or western pigs is an effective method to increase its growth performance and meat quality (Marsico et al. 2010; Zhang et al. 2015). In this study, we compared the growth performance, chemical composition, and FAA composition of three breeds (Wild boar, Bamei, and Yorkshire) and their crossing systems (Wild boar × Bamei and Wild boar × Yorkshire). As we expected, the cross breeding was shown to be a promising method to improve growth performance of wild boars, but crossing with different dam line breeds caused different responses (Visscher et al. 2000).

Compared with other breeds, wild boars had worse growth rate, but better meat quality and FAA composition (Wang et al. 2013). Meanwhile, both crossing systems resulted in overall improvement of growth and meat quality traits of hybrid boars (Wang et al. 2013). Furthermore, in terms of the performance, the current results were to some extent in agreement with the results of other related reports (Muller et al. 2000; Marsico et al. 2010). For example, wild boar had low daily live weight gain, but other growth performances (e.g. weights of organs and ADG) of hybrid pigs (wild boar × Pietrain and wild boar × Meishan) were significant improved (Müller et al. 2000). To compare meat quality between special wild boar with 75% wild boar blood and domestic pig, the meat of special wild boar had higher protein, total amino acid, and flavour amino acid (Mao et al. 2010). In another study, as the decline of blood percentage, the ADG of wild boar was significantly improved (Zhang and Sun 2012). However, it is also hard to...
prove the crossing system is the best hybrid system in the improvement of growth performance and meat quality in wild boar.

Additionally, European and Chinese domestic pigs were probably domesticated from different subspecies of wild boar (Müller et al. 2000). Until now, phenotypic variation between diverse pig breeds and their wild ancestors became relevant because of an increasing interest in Quantitative Trait Locus (QTL) mapping, meat quality, or the performance trait values (Andersson-Eklund et al. 1998; Müller et al. 2000; Nii et al. 2005; Razmaite et al. 2009). Unfortunately, there was no evidence to compare the levels of FAA or AA in wild boar and genetically diverse domestic breeds.

Interestingly, revealed in Figure 1 and Table 4, total FAA and total FAA/total AA in wild boar was significant higher than other breeds and cross combinations. Thus, the level of FAA was also affected by the breeds and hybridisation. Actually, the levels of FAA or AA in muscle were also influenced by multi-factors including breed, cross combinations, sex, different tissues, genotype, the level of dietary protein, and age (Mahan and Shield 1998; Morales et al. 2011). These results were in accordance with previous reports that the composition of FAA or AA in muscle had similar tendency in pig, goat, impala, broiler chicken, and fish (Wesselinova 2000; Hoffman and Ferreira 2004; Webb et al. 2005; Jiang et al. 2011; Kobayashi et al. 2013). Each animal body protein had its individual-specific amino acid composition, maintenance need, and turnover rate. The rate and priority of development of each proteinaceous tissue were also different from the other body tissues as the animal grows (Mahan and Shields 1995). Herein, the levels of total FAA or total FAA/total AA reflected the accumulated total quantity of AA which retained in all body components (Mahan and Shields Jr. 2006) also proposed that changes in relative tissue mass in combination with differences in AA composition among tissues contributed to changes of the AA composition of whole body protein.

In view of such a particular important biological function in animal and human (Wu 2009; Kim et al. 2011; Wang et al. 2013), to reveal the levels and change laws of FAA in different breeds and cross combinations pigs was helpful to explore the huge potential of FAA. Furthermore, the relationship between FAA and meat quality need much more studies on improving both meat quality and growth performance on in next research.

Conclusion

In this study, the cross breeding with domesticated pigs was shown to be an effective method to improve the growth performance (ADG) and FAA composition of wild boars, and the extent of improvement was breed dependent. Compared with domesticated pigs and cross-bred pigs, wild boars showed lower growth rate, but lower IMF and better FAA composition in longissimus muscle. The results can be used to protect and develop the wild boar resource, and to breed some special commercial lines with those originating from wild boars in the future.

Disclosure statement

No potential conflict of interest was reported by the authors.

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