Effects of Lactobacillus delbrueckii on Production Performance, Carcass Traits, and Meat Quality of Ningxiang Pigs: Postprint

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Abstract

This study aimed to investigate the effects of Lactobacillus delbrueckii on growth performance, carcass traits, and meat quality of Ningxiang pigs. Forty-eight Ningxiang pigs with an initial body weight of (33.28±1.15) kg were randomly divided into 2 groups, with 4 replicate pens per group and 6 pigs per pen. The control group was fed a basal diet without antibiotics, while the experimental group was fed a test diet supplemented with 0.2% Lactobacillus delbrueckii preparation in the basal diet. The experimental pigs were fed in two phases, namely 30–70 kg and 71–100 kg. The experimental period lasted 120 days. The results showed: In terms of growth performance, compared with the control group, the final body weight and average daily gain of pigs in the experimental group were slightly increased in both phases, and the feed conversion ratio was slightly decreased, but none of these changes were significant ($P>0.05$); Regarding carcass traits, there was a slight improvement, but no significant differences were observed in any indicators between the two groups ($P>0.05$); In terms of meat quality, compared with the control group, the yellowness value at 45 min post-slaughter and the lightness value and drip loss at 24 h post-slaughter of pigs in the experimental group were significantly decreased ($P<0.05$), while no significant differences were found in other indicators ($P>0.05$). It can be concluded that dietary supplementation with 0.2% Lactobacillus delbrueckii preparation can improve the growth performance, carcass traits, and meat quality of Ningxiang pigs.

Full Text

Effects of *Lactobacillus delbrueckii* on Performance, Carcass Trait and Meat Quality of Ningxiang Pigs

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Abstract: This experiment was conducted to investigate the effects of *Lactobacillus delbrueckii* on the performance, carcass traits, and meat quality of Ningxiang pigs. Forty-eight Ningxiang pigs with an initial body weight of (33.28±1.15) kg were randomly allocated into two groups, with four replicate pens per group and six pigs per pen. The control group was fed a basal diet without antibiotics, while the experimental group received the basal diet supplemented with 0.2% *Lactobacillus delbrueckii* preparation. The feeding trial was conducted in two stages: 30–70 kg and 71–100 kg, with a total experimental period of 120 days. The results showed that in terms of performance, the final weight and average daily gain of pigs in the experimental group were slightly higher, and the feed-to-gain ratio was slightly lower compared with the control group during both stages, but these differences were not significant ($P>0.05$). For carcass traits, slight improvements were observed, yet no significant differences were found between the two groups for any measured parameters ($P>0.05$). Regarding meat quality, compared with the control group, the yellowness value at 45 minutes post-slaughter and the lightness value and water loss rate at 24 hours post-slaughter were significantly decreased in the experimental group ($P<0.05$), while no significant differences were detected in other indices ($P>0.05$). These findings indicate that dietary supplementation with 0.2% *Lactobacillus delbrueckii* preparation can improve the performance, carcass traits, and meat quality of Ningxiang pigs.

Keywords: *Lactobacillus delbrueckii*; Ningxiang pig; growth performance; carcass trait; meat quality

With the development of society and improvement in living standards, people are paying increasing attention to their health and the nutritional quality of food. As pork represents one of the most important animal-derived food sources, improving meat quality has become a focal point in animal nutrition research. Previous studies have demonstrated that lactic acid bacteria effectively regulate gastrointestinal ecological balance, promote nutrient absorption, enhance immunity, improve animal performance, and ameliorate meat quality. Ningxiang pig is a renowned local fatty-type breed in China, characterized by high reproductive capacity, strong stress resistance, and high nutritional value. However, excessive fat deposition, slow growth rate, and long feeding periods

limit its economic benefits and widespread adoption. *Lactobacillus delbrueckii*, belonging to the genus *Lactobacillus*, holds broad application prospects in animal husbandry, food, and pharmaceutical industries. Current research on *L. delbrueckii* in swine production has primarily focused on lean-type breeds, with few studies investigating its effects on local fatty-type breeds. Therefore, this experiment aimed to examine the influence of dietary *L. delbrueckii* supplementation on the performance, carcass traits, and meat quality of Ningxiang pigs, explore its application efficacy in this breed, provide guidance for its promotion in local pig breeds, and offer scientific evidence for improving the performance, carcass traits, and meat quality of local breeds through dietary interventions.

1.1 Experimental Material

Lactobacillus delbrueckii was provided by the Microbiology Laboratory of the College of Animal Science and Technology, Hunan Agricultural University (preservation number: M207038), with a viable count of 2.0×10^{1} CFU/g.

1.2 Experimental Diets

The basal diet was a corn-soybean meal type formulated as extruded powder according to NY/T 65-2004. Based on the growth characteristics of Ningxiang pigs, two basal diets were prepared for Stage I (30–70 kg) and Stage II (71–100 kg). The composition and nutrient levels are presented in Table 1 .

Table 1 Composition and nutrient levels of basal diets (air-dry basis), %

Item	Stage I (30–70 kg)	Stage II (71–100 kg)
Ingredients		
Corn	68.00	70.00
Soybean meal	18.00	15.00
Wheat bran	8.00	10.00
CaHPO	1.50	1.50
Lys	0.30	0.30
Zeolite	0.50	0.50
Limestone	1.00	1.00
NaCl	0.30	0.30
SDA	0.10	0.10
Premix[1]	2.30	2.30
Total	**100.00**	**100.00**
Nutrient levels[2]		
DE (MJ/kg)	13.18	13.14
CP	15.50	14.50
Total Lys	0.78	0.70
Total Met	0.24	0.22
Total Thr	0.58	0.54
Ca	0.65	0.63

Item	Stage I (30–70 kg)	Stage II (71–100 kg)
TP	0.55	0.53
AP	0.28	0.28
CF	3.20	3.50

[1]Premix provided per kg of diet: VA 4,060 IU, VD 2,030 IU, VE 40.6 IU, VK 4.0 mg, VB 20.0 g, VB 2.0 mg, VB 8.0 mg, pantothenic acid 15.2 mg, niacin 20.3 mg, choline chloride 609 mg, Mn 61.8 mg, Fe 109.2 mg, Zn 104 mg, Cu 22 mg, I 0.3 mg, Se 0.31 mg.
[2]Nutrient levels were calculated values.

1.3 Experimental Design and Sample Collection

A single-factor randomized design was employed. Forty-eight Ningxiang pigs with similar origin, same parity, comparable age, and initial body weight of (33.28±1.15) kg were randomly divided into two groups, with four replicate pens per group and six pigs per pen. The control group received the antibiotic-free basal diet, while the experimental group was fed the basal diet supplemented with 0.2% *Lactobacillus delbrueckii* preparation for 120 days.

At the end of the trial, after 24 hours of fasting with free access to water, one pig with body weight close to the pen average was randomly selected from each pen for slaughter. Following slaughter, the carcass was split and the left half was retained after removing the head, tail, feet, and viscera for carcass trait evaluation. The *longissimus dorsi* muscle from the left carcass was collected for meat quality analysis.

1.4 Animal Management

The feeding trial was conducted at a commercial pig farm in Ningxiang County, Changsha City, Hunan Province. During the experimental period, pigs were fed twice daily at 09:00 and 16:00, with ad libitum access to feed and water. Routine management and immunization protocols followed standard farm practices.

1.5 Measurement Indices

1.5.1 Performance Pigs were weighed after fasting on days 1, 60, and 120 to calculate average daily gain (ADG). Health status was monitored daily, and feed consumption was recorded for each replicate to determine average daily feed intake (ADFI). The feed-to-gain ratio (F/G) was calculated based on ADG and ADFI.

1.5.2 Carcass Traits Carcass weight, fat percentage, dressing percentage, backfat thickness, skin thickness, carcass length, lean meat percentage, and loin eye area were measured according to the Technical Specification for Carcass Trait Measurement of Lean-Type Pigs (NY/T 825-2004).

The left carcass was separated into skin, bone, fat, lean meat, and leaf lard. Intramuscular fat was counted as lean meat, while skin muscle, cartilage, and tendon were counted as fat. Each component was weighed separately. Lean meat percentage was calculated as lean weight divided by the sum of skin, bone, fat, and lean weights; fat percentage as fat weight divided by the same sum; and leaf lard rate as leaf lard weight divided by carcass weight.

1.5.3 Meat Quality Following the Technical Specification for Pork Quality Measurement (NY/T 821-2004), *longissimus dorsi* samples were stored at 4°C, and meat quality parameters including pH and color were measured at 45 minutes and 24 hours post-slaughter. Water loss rate was determined using a digital muscle tenderness meter (C-LM3B), meat color with a colorimeter (CR-400), water-holding capacity with a compression meter (PY-1), and pH with a pH meter (testo 205). Meat color and marbling scores were evaluated using the 5-point scale of the American NPPC color standard (1991 version).

1.5.4 Nutrient Content of *Longissimus Dorsi* *Longissimus dorsi* samples were removed from -20°C storage, sliced, placed in plastic cups, and freeze-dried for 24 hours using a freeze dryer (LGJ-10C). The dried samples were then ground and stored for analysis. Intramuscular fat content was determined according to GB/T 9695.7—2008, and crude protein content was measured using a Kjeldahl apparatus following GB/T 9695.11—2008.

1.5.5 Muscle Fiber Diameter and Area of *Longissimus Dorsi* *Longissimus dorsi* tissue was processed according to the method of Yang Peige et al. [7], sectioned, stained with hematoxylin-eosin (HE), and examined microscopically to calculate muscle fiber diameter and area.

1.6 Statistical Analysis

Experimental data were processed using Excel 2003 and analyzed by t-test using SPSS 18.0 software. Differences were considered significant at $P<0.05$ and highly significant at $P<0.01$. Results are expressed as mean ± standard deviation.

2.1 Effects of *Lactobacillus delbrueckii* on Performance of Ningxiang Pigs

As shown in Table 2 , compared with the control group, the final weight and ADG of the experimental group increased by 2.97% and 3.99% ($P>0.05$), respectively, while F/G decreased by 2.92% ($P>0.05$) during Stage I. During Stage II, final weight and ADG increased by 2.33% and 3.21% ($P>0.05$), respectively, and F/G decreased by 3.84% ($P>0.05$). Over the entire experimental period, ADG increased by 2.17% ($P>0.05$) and F/G decreased by 2.27% ($P>0.05$).

Table 2 Effects of *Lactobacillus delbrueckii* on performance of Ningxiang pigs

Item	Control group	Experimental group	P-value
Stage I			
Initial weight (kg)	32.84±1.47	33.73±0.63	
Final weight (kg)	70.81±1.71	72.91±1.21	
ADG (g)	632.99±12.44	658.23±32.17	
ADFI (g)	2382.29±102.41	2389.42±112.91	
F/G	3.77±0.21	3.66±0.18	
Stage II			
Final weight (kg)	93.25±2.01	95.47±1.74	
ADG (g)	364.24±29.01	375.94±24.39	
ADFI (g)	1601.62±84.30	1598.21±74.61	
F/G	4.43±0.57	4.26±0.24	
Whole stage			
ADG (g)	503.47±22.59	514.48±14.47	
ADFI (g)	1991.96±88.40	1993.81±78.10	
F/G	3.97±0.36	3.88±0.13	

In the same row, values with the same or no letter superscripts indicate no significant difference (P>0.05), while different lowercase letters indicate significant difference (P<0.05). The same applies below.

2.2 Effects of *Lactobacillus delbrueckii* on Carcass Traits of Ningxiang Pigs

As shown in Table 3 , compared with the control group, carcass weight, dressing percentage, lean meat percentage, loin eye area, body straight length, and body slanting length of the experimental group increased by 2.74%, 1.51%, 5.51%, 5.12%, 0.33%, and 4.92%, respectively, while leaf lard rate, fat percentage, backfat thickness, and skin thickness decreased by 13.00%, 2.13%, 2.57%, and 10.85%, respectively. However, none of these changes were significant (P>0.05).

Table 3 Effects of *Lactobacillus delbrueckii* on carcass traits of Ningxiang pigs

Item	Control group	Experimental group	P-value
Slaughter weight (kg)	94.62±3.30	96.00±2.35	
Carcass weight (kg)	70.40±8.56	72.33±2.58	
Dressing rate (%)	74.30±7.68	75.42±4.59	
Lean meat rate (%)	33.22±2.31	35.05±1.76	
Fat rate (%)	46.57±3.42	45.58±3.54	
Leaf lard rate (%)	3.00±0.49	2.61±0.56	
Body straight length (cm)	75.75±2.87	76.00±2.58	
Body slanting length (cm)	66.00±3.08	69.25±4.11	
Backfat thickness (mm)	50.92±4.81	49.61±1.44	
Skin thickness (mm)	4.70±0.38	4.19±0.65	

Item	Control group	Experimental group	P-value
Loin eye area (cm^2)	20.52±1.94	21.57±1.39	

2.3 Effects of *Lactobacillus delbrueckii* on Meat Quality of Ningxiang Pigs

As shown in Table 4 , compared with the control group, the redness value and marbling score at 45 minutes post-slaughter in the experimental group increased by 6.98% and 17.36% (P>0.05), respectively, while lightness value, yellowness value, meat color score, pH, cooking loss, and water loss rate decreased by 0.29% (P>0.05), 22.70% (P<0.05), 3.56% (P>0.05), 0.45% (P>0.05), 2.40% (P>0.05), and 9.72% (P>0.05), respectively. At 24 hours post-slaughter, redness value, meat color score, marbling score, and pH increased by 16.48%, 4.17%, 22.54%, and 0.45% (P>0.05), respectively, while lightness value, yellowness value, cooking loss, and water loss rate decreased by 8.72% (P<0.05), 3.70% (P>0.05), 26.99% (P>0.05), and 13.33% (P<0.05), respectively.

Table 4 Effects of *Lactobacillus delbrueckii* on meat quality of Ningxiang pigs

Item	Control group	Experimental group	P-value
45 min post-slaughter			
L* value	44.46±1.61	44.33±0.92	
a* value	8.02±0.40	8.58±0.79	
b* value	3.70±0.47	2.86±0.34	<0.05
Meat color score	3.37±0.26	3.25±0.29	
Marbling score	2.88±0.63	3.38±0.48	
Cooking loss (%)	61.70±2.64	60.22±1.75	
Water loss rate (%)	15.84±2.03	14.30±1.67	
24 h post-slaughter			
L* value	51.74±2.22	47.23±1.89	<0.05
a* value	7.04±1.41	8.20±1.27	
b* value	4.32±0.34	4.16±0.52	
Meat color score	3.12±0.25	3.25±0.29	
Marbling score	2.75±0.50	3.37±0.25	
pH	5.41±0.03	5.43±0.10	
Cooking loss (%)	31.58±2.41	27.37±2.08	<0.05
Water loss rate (%)	2.89±0.60	2.11±0.34	

2.4 Effects of *Lactobacillus delbrueckii* on Nutrient Content of *Longissimus Dorsi*

As shown in Table 5 , compared with the control group, the crude protein content in the *longissimus dorsi* of the experimental group increased by 1.01% (P>0.05), while intramuscular fat content decreased by 1.68% (P>0.05).

Table 5 Effects of *Lactobacillus delbrueckii* on nutrient contents of *longissimus dorsi* of Ningxiang pigs

Item	Control group	Experimental group	P-value
CP	77.00±2.09	77.78±2.00	
IMF	19.59±0.62	19.26±0.73	

2.4 Effects of *Lactobacillus delbrueckii* on Muscle Fiber Area and Diameter of *Longissimus Dorsi*

As shown in Table 6 , the muscle fiber area and diameter in the *longissimus dorsi* of the experimental group decreased by 8.43% and 6.07%, respectively, compared with the control group, but these changes were not significant (P>0.05).

Table 6 Effects of *Lactobacillus delbrueckii* on muscle fiber area and diameter of *longissimus dorsi* of Ningxiang pigs

Item	Control group	Experimental group	P-value
Myofiber area (m^2)	3,206.42±272.24	2,936.17±164.34	
Myofiber diameter (m)	57.37±3.05	53.89±3.25	

3.1 Effects of *Lactobacillus delbrueckii* on Performance of Ningxiang Pigs

Research has shown that lactic acid bacteria produce lactic acid to lower intestinal pH, promote the growth of beneficial gastrointestinal microorganisms, and establish a dominant beneficial microflora in the digestive tract. These bacteria also produce nutrients and digestive enzymes that enhance nutrient digestion and absorption, thereby improving animal performance. Dowarah et al. [11] reported that lactic acid bacteria significantly increased average daily gain and feed intake while decreasing the feed-to-gain ratio in growing-finishing pigs. Zhang et al. [12] found that supplementation with *Lactobacillus plantarum* GF103 improved feed conversion efficiency and growth rate in growing pigs. Chen et al. [13] demonstrated that a combination of *Lactobacillus acidophilus* and *Bacillus* significantly increased average daily gain in growing pigs. In the present study, the experimental group exhibited increased final weight and ADG and decreased F/G during both stages, consistent with the findings of Li et al. [14]. This may be attributed to the acid flavor imparted by *L. delbrueckii*, which improves diet palatability. After ingestion, *L. delbrueckii* colonizes the digestive tract, modulates microecological balance, increases villus height and crypt depth, and expands the absorptive surface area for nutrients, consequently enhancing pig performance.

3.2 Effects of *Lactobacillus delbrueckii* on Carcass Traits of Ningxiang Pigs

Carcass traits in pigs are primarily reflected by dressing percentage, lean meat percentage, loin eye area, and backfat thickness. Studies have shown that dietary lactic acid bacteria supplementation improves carcass traits in pigs. Hou et al. [5] reported that 0.1% *L. delbrueckii* supplementation increased loin eye area and lean meat percentage while decreasing backfat thickness in growing-finishing pigs. He [16] observed that microecological preparations containing lactic acid bacteria tended to increase loin eye area in growing-finishing pigs. The current study found that the experimental group exhibited increased lean meat percentage and loin eye area along with decreased fat percentage, indicating that *L. delbrueckii* can improve carcass traits. This effect may be related to the ability of lactic acid bacteria to produce various active compounds that activate lipase, promote fat decomposition and energy release, inhibit carbohydrate oxidation and conversion, and increase protein content in the body [17-19]. The underlying mechanisms require further investigation.

3.3 Effects of *Lactobacillus delbrueckii* on Meat Quality of Ningxiang Pigs

Pork palatability and eating quality determine consumer acceptance, which is evaluated through indices such as pH, marbling, meat color, and tenderness [20]. Numerous studies have demonstrated that lactic acid bacteria can alleviate post-slaughter pH decline, improve meat color, reduce drip loss and cooking loss, enhance water-holding capacity, decrease shear force, and improve pork quality [21-23]. Meng et al. [24] found that probiotics increased meat color scores and redness values in growing-finishing pigs. Wei et al. [25] reported that microecological preparations containing lactic acid bacteria significantly reduced storage loss while improving marbling scores, meat color scores, and water-holding capacity in finishing pigs. The present results showed that the experimental group had significantly lower yellowness values at 45 minutes post-slaughter and lightness values and water loss rates at 24 hours post-slaughter, consistent with previous studies [26-27]. These findings suggest that *L. delbrueckii* supplementation can improve pork quality, possibly by enhancing nutrient absorption efficiency in the digestive tract and regulating body nutrient composition, though the specific mechanisms warrant further research.

3.4 Effects of *Lactobacillus delbrueckii* on Nutrient Content and Muscle Fiber Characteristics of *Longissimus Dorsi*

Nutrient content is a crucial indicator for evaluating muscle quality, and changes in nutrient composition, particularly intramuscular fat and protein content, directly affect meat sensory properties and nutritional characteristics [28]. Intramuscular fat forms the material basis for meat tenderness, juiciness, and flavor, and its increase improves meat color, tenderness, juiciness, and flavor [29]. This study found that dietary *L. delbrueckii* supplementation increased crude pro-

tein content while decreasing intramuscular fat content in the *longissimus dorsi*, similar to the results of Hou et al. [5], indicating that *L. delbrueckii* can improve nutrient deposition in porcine *longissimus dorsi*.

Extensive research has shown that finer muscle fibers correlate with more tender meat, whereas coarser fibers indicate poorer meat quality. Muscle fiber area increases with age. Studies have reported that foreign lean-type breeds such as Duroc-Landrace-Yorkshire, Large White, and Landrace have muscle fiber diameters of 54–73 m, while Chinese local breeds have diameters of 44–57 m [30]. The present study found that *L. delbrueckii* supplementation tended to decrease muscle fiber diameter and area in the *longissimus dorsi*, possibly by modulating connective tissue and intramuscular fat content, thereby affecting muscle fiber characteristics in Ningxiang pigs.

Conclusion

Dietary supplementation with 0.2% *Lactobacillus delbrueckii* preparation can improve the performance, carcass traits, and meat quality of Ningxiang pigs.

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Note: Figure translations are in progress. See original paper for figures.