Effects of Dietary Digestible Energy, Crude Protein, and Crude Fiber Levels on Growth Performance, Carcass Traits, and Meat Quality of Finishing Sujiang Pigs (Postprint)

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Date: 2018-12-24T00:00:00+00:00

Abstract

This experiment aimed to investigate the effects of dietary digestible energy, crude protein, and crude fiber levels on growth performance, carcass traits, and meat quality of finishing Sujiang pigs. The experiment utilized 162 Sujiang pigs with a body weight of (50.49$±$4.78) kg, randomly allocated into 9 groups, with 3 replicates per group and 6 pigs per replicate (half male and half female). A 3-factor 3-level orthogonal experimental design was employed, with digestible energy levels of 11.64, 12.24, and 12.84 MJ/kg, crude protein levels of 12%, 13%, and 14%, and crude fiber levels of 5%, 8%, and 11%, to formulate 9 diets. The pre-trial period lasted 7 days, and the formal trial period lasted 42 days. The results showed: 1) The average daily feed intake (ADFI) of the 11.64 MJ/kg digestible energy group was significantly higher than that of the 12.24 and 12.84 MJ/kg digestible energy groups ($P < 0.05$); dietary digestible energy level had no significant effect on average daily gain (ADG) and feed-to-gain ratio (F/G) of the experimental pigs ($P > 0.05$). Dietary crude protein level had no significant effect on ADG, ADFI, and F/G of the experimental pigs ($P > 0.05$). The ADG, ADFI, and F/G of the 8% and 11% crude fiber groups were significantly higher ($P < 0.05$), extremely significantly higher ($P < 0.01$), and extremely significantly lower ($P < 0.01$) than those of the 5% crude fiber group, respectively. 2) The dressing percentage and carcass length of the 12.24 MJ/kg digestible energy group were significantly higher than those of the 11.64 MJ/kg digestible energy group ($P < 0.05$); the average backfat thickness of the 11% crude fiber group was extremely significantly lower than that of the 5% crude fiber group ($P < 0.01$). 3) The muscle redness value of the 12.84 MJ/kg digestible energy group was extremely significantly higher than that of the 11.64 and 12.24 MJ/kg digestible energy groups ($P < 0.01$); the muscle pH at 24 h

of the 13% crude protein group was significantly lower than that of the 12% crude protein group ($P < 0.05$); the intramuscular fat content of the 8% and 11% crude fiber groups was extremely significantly lower than that of the 5% crude fiber group ($P < 0.01$). Taking all these factors into consideration, the appropriate levels of digestible energy, crude protein, and crude fiber in diets for finishing Sujiang pigs were 12.84 MJ/kg, 12%, and 11%, respectively.

Full Text

Effects of Dietary Digestible Energy, Crude Protein and Crude Fiber Levels on Growth Performance, Carcass Traits and Meat Quality of Fattening Sujiang Pigs

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Abstract: This study aimed to investigate the effects of dietary digestible energy (DE), crude protein (CP) and crude fiber (CF) levels on growth performance, carcass traits and meat quality of fattening Sujiang pigs. A total of 162 Sujiang pigs with a body weight of (50.49$±$4.78) kg were randomly allocated to 9 groups, with 3 replicates per group and 6 pigs per replicate (half male and half female). A three-factor three-level orthogonal experimental design was adopted to formulate 9 diets with three DE levels (11.64, 12.24 and 12.84 MJ/kg), three CP levels (12%, 13% and 14%), and three CF levels (5%, 8% and 11%). The prefeeding period lasted for 7 days and the formal feeding period lasted for 42 days. The results showed: 1) The average daily feed intake (ADFI) of pigs in the 11.64 MJ/kg DE group was significantly higher than that in the 12.24 and 12.84 MJ/kg DE groups ($P < 0.05$), but dietary DE level had no significant effect on average daily gain (ADG) and feed/gain ratio (F/G) ($P > 0.05$). Dietary CP level had no significant effects on ADG, ADFI and F/G ($P > 0.05$). The ADG, ADFI and F/G of pigs in the 8% and 11% CF groups were significantly higher ($P < 0.05$), extremely significantly higher ($P < 0.01$) and extremely significantly lower ($P < 0.01$) than those in the 5% CF group, respectively. 2) The dressing percentage and carcass length of pigs in the 12.24 MJ/kg DE group were significantly higher than those in the 11.64 MJ/kg DE group ($P < 0.05$). The average backfat thickness of pigs in the 11% CF group was extremely significantly lower than that in the 5% CF group ($P < 0.01$). 3) The muscle redness value (a*) of pigs in the 12.84 MJ/kg DE group was extremely significantly higher than that in the 11.64 and 12.24 MJ/kg DE groups ($P < 0.01$). The muscle pH at 24 h (pH24h) of pigs in the 13% CP group was significantly lower than that in the 12% CP group ($P < 0.05$). The intramuscular fat content of pigs in the 8% and 11% CF groups was extremely significantly

lower than that in the 5% CF group ($P < 0.01$). Based on comprehensive consideration of the above factors, the appropriate DE, CP and CF levels in diets for fattening Sujiang pigs were 12.84 MJ/kg, 12% and 11%, respectively.

Keywords: Sujiang pigs; digestible energy level; crude protein level; crude fiber level; growth performance; carcass traits; meat quality

Introduction

The Sujiang pig is a new breed developed through crossbreeding and inter-se mating fixation over 17 years and six generations, and was approved by the National Animal Genetic Resources Commission of the Ministry of Agriculture in July 2013 [1]. Sujiang pigs exhibit excellent growth, carcass and meat quality performance, inheriting the advantages of high feed efficiency, high lean meat percentage and fast growth rate from their Duroc sire line, while maintaining the characteristics of superior meat quality, high intramuscular fat content and roughage tolerance from the Jiangquhai dam line. However, objective and scientific evaluation of Sujiang pork quality is still lacking, and studies on its nutritional requirements and roughage tolerance are rare.

The main indicators for evaluating pork quality generally include meat color, pH, marbling score, shear force, drip loss rate and intramuscular fat content. Dietary factors affecting pork quality mainly include ingredient type, feeding method, feed additives and nutrient levels [2]. Different levels of energy, crude protein and amino acids, crude fiber, and trace minerals in diets can all affect the taste and flavor of pork. Moreover, the nutrient deposition level of pigs during the fattening stage is more directly affected by diet, thus growth performance and carcass traits can be improved by regulating dietary nutrient levels. Rong et al. [3] studied the effects of different crude fiber levels on meat quality of Huai pigs and found that high-fiber diets significantly improved muscle tenderness. Rotz [4] reported that dietary crude protein level can affect muscle protein deposition, thereby influencing meat quality. However, current research mainly focuses on the effects of single nutrients on pork quality [5-6], while comprehensive evaluation studies on the effects of multiple nutrients on pork quality are lacking. Meanwhile, there are no relevant reports on the nutrient requirements of Sujiang pigs. Therefore, this study aimed to analyze the effects of different dietary DE, CP and CF levels on growth performance, carcass traits and meat quality of fattening Sujiang pigs, in order to provide a reference basis for the formulation of feeding standards and grain-saving diet formulation for Sujiang pigs.

1. Materials and Methods

1.1 Experimental Animals

A total of 162 healthy Sujiang pigs with a body weight of (50.49$±$4.78) kg, similar parity, weaning age and age were selected as experimental animals.

1.2 Experimental Design

The selected Sujiang pigs were randomly divided into 9 groups at a male-to-female ratio of 1:1, with 3 replicates per group and 6 pigs per replicate. A three-factor three-level L9(34) orthogonal experimental design was used (Table 1). Based on the Chinese "Feeding Standard of Swine" (NY/T 65-2004) for lean-type pigs and previous feeding experience, three DE levels (11.64, 12.24 and 12.84 MJ/kg), three CP levels (12%, 13% and 14%), and three CF levels (5%, 8% and 11%) were established to design 9 feed formulas, which were used as diets for the 9 groups. Except for DE, CP and CF levels, other nutrient levels were the same among groups. Diet composition and nutrient levels are shown in Table 2 . The feeding trial was conducted at Jiangsu Sujiang Breeding Pig Co., Ltd. from March to May 2017. Before the trial, feeding equipment and pens were disinfected according to routine procedures. During the trial, pigs had free access to feed and water under conventional management. The prefeeding period lasted for 7 days and the formal feeding period lasted for 42 days.

1.3 Measurement Indicators

1.3.1 Growth Performance At the beginning and end of the formal feeding period, pigs were weighed at 08:00 after fasting by replicate, and daily feed intake was recorded by replicate to calculate average daily gain (ADG), average daily feed intake (ADFI) and feed/gain ratio (F/G) of fattening Sujiang pigs.

1.3.2 Carcass Traits Six Sujiang pigs were randomly selected from each group and slaughtered after 24 h of fasting (with free access to water). Sample collection and measurements were conducted according to NY/T 825-2004 "Technical Specification for Carcass Trait Measurement of Lean-type Pigs" [7]. Measured indicators included carcass weight, dressing percentage, leaf fat proportion, average backfat thickness, carcass length and loin-eye area.

1.3.3 Meat Quality After slaughter, sample collection and determination of muscle pH at 24 h (pH24h), meat color, drip loss rate and shear force were conducted according to NY/T 1333-2007 "Determination of Livestock and Poultry Meat Quality" [8]. The marbling score of fresh muscle surface was evaluated according to the marbling score chart (NPPC, 1991) with scores ranging from 1 to 5. Intramuscular fat content was determined according to GB 5009.6-2016 "Determination of Fat in Foods" [9].

1.4 Data Processing and Statistical Analysis

Experimental data were first preliminarily processed using Excel 2007 software, and then subjected to orthogonal design analysis of variance using SPSS 19.0 statistical software. Duncan' s multiple comparison test was used for pairwise comparisons among observations. Final results were expressed as means and standard deviations. $P < 0.05$ and $P < 0.01$ indicated significant and extremely significant differences, respectively.

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2. Results

2.1 Effects of Dietary DE, CP and CF Levels on Growth Performance of Fattening Sujiang Pigs

As shown in Table 3 , dietary DE level had no significant effect on ADG and F/G ($P > 0.05$). The ADFI was highest in the 11.64 MJ/kg DE group, which was extremely significantly higher than that in the 12.24 and 12.84 MJ/kg DE groups ($P < 0.01$). Dietary CP level had no significant effects on ADG, ADFI and F/G ($P > 0.05$). The ADG, ADFI and F/G of pigs in the 8% and 11% CF groups were significantly higher ($P < 0.05$), extremely significantly higher ($P < 0.01$) and extremely significantly lower ($P < 0.01$) than those in the 5% CF group, respectively. However, there were no significant differences in ADG, ADFI and F/G between the 8% and 11% CF groups ($P > 0.05$).

2.2 Effects of Dietary DE, CP and CF Levels on Carcass Traits of Fattening Sujiang Pigs

As shown in Table 4 , dietary DE level had no significant effect on carcass weight, leaf fat proportion, average backfat thickness and loin-eye area ($P > 0.05$). The dressing percentage and carcass length were highest in the 12.24 MJ/kg DE group, which were significantly higher than those in the 11.64 MJ/kg DE group ($P < 0.05$), but showed no significant difference from the 12.84 MJ/kg DE group ($P > 0.05$). Dietary CP level had no significant effect on any carcass trait indicators ($P > 0.05$). With the increase of dietary CF level, the average backfat thickness of pigs showed a decreasing trend, with the 11% CF group being extremely significantly lower than the 5% CF group ($P < 0.01$). No significant differences were observed in other carcass traits among CF groups ($P > 0.05$).

2.3 Effects of Dietary DE, CP and CF Levels on Meat Quality of Fattening Sujiang Pigs

As shown in Table 5 , except that the redness value (a*) of pigs in the 12.84 MJ/kg DE group was extremely significantly higher than that in the 11.64 and 12.24 MJ/kg DE groups ($P < 0.01$), dietary DE level had no significant effect on other meat quality indicators ($P > 0.05$). Except that the pH24h of pigs in

the 13% CP group was significantly lower than that in the 12% CP group ($P < 0.05$), dietary CP level had no significant effect on other meat quality indicators ($P > 0.05$). Except that the intramuscular fat content of pigs in the 8% and 11% CF groups was extremely significantly lower than that in the 5% CF group ($P < 0.01$), dietary CF level had no significant effect on other meat quality indicators ($P > 0.05$).

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3. Discussion

As a newly developed excellent lean-type pig breed, the nutritional requirements and feeding standards of Sujiang pigs have not been thoroughly studied. Based on the Chinese "Feeding Standard of Swine," this study investigated for the first time the effects of diets with different DE, CP and CF levels on growth performance, carcass traits and meat quality of fattening Sujiang pigs to explore their appropriate nutrient requirements. Pigs of different breeds and under different farming conditions require different nutrient levels to achieve high production performance and high-quality pork products.

3.1 Effects of Dietary DE, CP and CF Levels on Growth Performance of Fattening Sujiang Pigs

Dietary nutrition is a key factor affecting pig growth performance besides genetics and environment, and DE level is one of the important factors. Many studies have reported that feed intake of pigs is affected by dietary energy level, which decreases gradually with increasing dietary energy level [10-12]. This study obtained consistent results, as the ADFI of fattening Sujiang pigs decreased significantly when dietary DE level increased from 11.64 MJ/kg to 12.24 MJ/kg. Some studies suggest that increased dietary energy level can increase blood leptin concentration, which inhibits the secretion of hypothalamic neuropeptide Y to regulate feed intake [13]. Zou et al. [11] and Yang [12] found that increasing dietary DE level decreased F/G in pigs, while Li et al. [14] reported that increasing dietary energy level improved ADG and decreased F/G in Gaopo pigs. However, in this study, increasing dietary DE level had no significant effect on ADG of fattening Sujiang pigs, and although F/G showed a decreasing trend, the effect was not significant, which may be due to breed differences and the range of DE levels set. From the perspective of growth performance, a dietary DE level of 12.24 MJ/kg is recommended for fattening Sujiang pigs.

According to the amino acid balance theory, reducing dietary CP level while supplementing synthetic amino acids does not affect animal growth performance [15]. Meanwhile, low-protein diets can reduce feeding costs and nitrogen pollution emissions [16]. Numerous studies have shown that under amino acid balance conditions, reducing dietary CP level has no significant effect on ADG, ADFI and F/G of pigs [5,17]. This study obtained consistent results: when dietary CP level decreased from 14% to 12% under the same dietary lysine and

methionine contents, the growth performance of fattening Sujiang pigs did not change significantly. However, Yang [12] showed that when dietary CP level decreased from 14% to 12%, ADG of finishing Wei pigs decreased and F/G increased; Tuitoek et al. [18] also reported that reducing dietary protein level while supplementing lysine and other amino acids decreased ADG and increased F/G of growing-finishing pigs. The differences between these reports and our results may be due to the fact that pig growth performance is affected by factors such as breed, growth stage and amino acid supplementation pattern, in addition to dietary CP level. Considering growth performance, feed cost and low-nitrogen emission reduction, a dietary CP level of 12% is recommended for fattening Sujiang pigs.

Pigs can tolerate relatively high levels of crude fiber when dietary energy level is satisfied [19]. The cecum of finishing pigs contains numerous fiber-decomposing bacteria that can ferment crude fiber into volatile fatty acids, which can meet 5%-30% of the energy requirement of pigs [20]. This study found that when dietary CF level increased from 5% to 11%, the ADFI of fattening Sujiang pigs decreased extremely significantly, which is consistent with the conclusion of Zhang et al. [6]. The decrease in feed intake may be due to the reduced palatability of diets caused by excessive fiber content, and the high satiety effect of fiber leaving no space in the digestive tract [21]. This study also showed that increasing dietary CF level helped improve growth performance of fattening Sujiang pigs, while some studies have reported that increasing CF level decreased ADG and increased F/G of pigs [22]. The differences among studies may be related to pig breed, growth stage, dietary fiber source and diet composition. Sujiang pigs have 37.5% local pig bloodline and inherited the roughage tolerance characteristic from the Jiangquhai dam line. It has been reported that dietary CF levels can reach 10% for Liaoning Black pigs [20] and 10.5% for Luchuan pigs [23], which are close to the maximum CF level of 11% set in this study. Appropriate dietary CF level can maintain normal gastrointestinal motility and stimulate gastrointestinal development [24]. The highest CF level group in this study achieved the best growth performance, revealing the roughage tolerance advantage of Sujiang pigs. However, the growth effect of further increasing CF level and the fiber utilization mechanism of Sujiang pigs warrant further study. In summary, the dietary CF level for fattening Sujiang pigs can be set at 11%.

3.2 Effects of Dietary DE, CP and CF Levels on Carcass Traits of Fattening Sujiang Pigs

Pig carcass traits mainly include carcass weight, dressing percentage, leaf fat proportion, average backfat thickness, carcass length and loin-eye area. This study found that when dietary DE level increased from 11.64 MJ/kg to 12.24 MJ/kg, the dressing percentage and carcass length of fattening Sujiang pigs increased significantly, which is basically consistent with the report of Beaulieu et al. [25]. Meanwhile, this study also showed that increasing dietary DE level had no significant effect on carcass traits such as backfat thickness and loin-

eye area, which is consistent with the conclusion of Zhou et al. [26]. However, Apple et al. [27] reported that increasing dietary energy level increased carcass weight and backfat thickness at the lumbar vertebrae and 10th rib; Li et al. [28] showed that increasing dietary energy level tended to increase loin-eye area and lean meat percentage of three-way crossbred pigs. These different conclusions may be related to muscle development patterns, growth time, slaughter weight, energy source and energy level settings. From the perspective of carcass traits, a dietary DE level of 12.24 MJ/kg is appropriate for fattening Sujiang pigs.

Dietary protein is the main raw material for pig carcass tissue composition and renewal. Studies have shown that increasing dietary CP level can promote body protein deposition. Li et al. [28] reported that increasing dietary CP level tended to increase lean meat percentage and loin-eye area of pigs. Ge et al. [29] reported that with decreasing dietary CP level, the lean meat percentage and loin-eye area of Wujin pigs decreased. However, Li et al. [5] and Huo et al. [30] both concluded that low-protein amino acid-balanced diets had no significant effect on carcass traits of growing-finishing pigs. This study also found that feeding diets with different CP levels (12%-14%) had no significant effect on any carcass trait indicators of fattening Sujiang pigs. Therefore, from the perspective of carcass traits, the dietary CP level for fattening Sujiang pigs can also be set at 12%.

Some studies have shown that increasing dietary CF level during the late fattening stage of pigs can reduce fat deposition and improve carcass traits [20]. This study further confirmed this conclusion: when dietary CF level increased from 5% to 11%, the average backfat thickness of fattening Sujiang pigs decreased significantly. Zhang et al. [6] reported that increasing dietary CF level significantly decreased backfat thickness and leaf fat proportion of finishing pigs, thereby improving their carcass traits, which is consistent with our results. However, with increasing dietary CF level, the dressing percentage of pigs generally decreased [12], which is believed to be due to the stimulation of crude fiber on gastrointestinal development, resulting in increased weight and volume of the digestive tract and increased residual chyme [31]. Therefore, increasing dietary CF level not only saves feed costs but also effectively improves pig carcass traits. From the perspective of carcass traits, a dietary CF level of 11% is appropriate for fattening Sujiang pigs.

3.3 Effects of Dietary DE, CP and CF Levels on Meat Quality of Fattening Sujiang Pigs

Dietary nutrient levels can affect meat quality indicators such as meat color, pH, drip loss rate and shear force [32]. Meat color is an important sensory quality of pork, where redness value indicates the change from red to green, with higher values indicating better meat quality. This study found that dietary DE level had no significant effect on most meat quality indicators such as drip loss rate and intramuscular fat content, but the muscle redness value of pigs fed the diet with 12.84 MJ/kg DE was significantly higher than that of pigs fed diets with 11.64 and 12.24 MJ/kg DE, indicating that high DE diets could change the

meat color of fattening Sujiang pigs, which is consistent with the results of Li et al. [14]. Meat color is related to the glycolysis rate of muscle glycogen after slaughter and is mainly determined by the chemical properties of myoglobin in muscle, which is affected by various factors, causing meat color to vary from gray-white to dark red [2]. In summary, based solely on meat quality indicators, the appropriate dietary DE level for fattening Sujiang pigs is 12.84 MJ/kg.

Increasing dietary CP level can improve pork water-holding capacity and shear force, but excessively high CP level can affect pork tenderness, juiciness and flavor [32]. Apple et al. [33] recently found that amino acid-balanced low-protein diets had no significant effect on pork meat color, water-holding capacity and other meat quality indicators. This study found that dietary CP level had no significant effect on meat color, drip loss rate, shear force, marbling score and intramuscular fat content of fattening Sujiang pigs, but increasing CP level decreased pork pH24h, which is consistent with the results of Yang [12]. The pH24h is affected by pig breed, muscle type, genetic factors, glycogen level, various enzyme activities and muscle buffering capacity [2]. High CP diets may lead to increased glycogen deposition in muscle, resulting in increased lactic acid production from muscle glycogen and ultimately lower pH [2]. There was little difference in meat quality among different CP level groups. For cost and emission reduction considerations, a dietary CP level of 12% is recommended for fattening Sujiang pigs.

Intramuscular fat content is an important factor affecting pork tenderness, juiciness and flavor. This study showed that when dietary CF level of fattening Sujiang pigs increased from 5% to 8%-11%, the intramuscular fat content in pork decreased significantly, which is consistent with the previous result of decreased average backfat thickness and also consistent with the report of Zhang et al. [6]. This may be because increasing dietary CF level reduces fat deposition in adipocytes of finishing pigs, thereby decreasing intramuscular fat content [6]. However, this study also found that increasing dietary CF level had no significant effect on meat quality indicators other than intramuscular fat content. Pork quality is not only related to intramuscular fat content, but also to specific fatty acid composition, inosinic acid, amino acids and other flavor substances in muscle [34]. Guo et al. [35] also found that increasing dietary CF level significantly decreased intramuscular fat content of Yantai Black pigs, but significantly increased the contents of tyrosine, phenylalanine and linoleic acid, suggesting that although high CF level decreased intramuscular fat content, it did not affect the overall pork quality. Cho et al. [36] reported that although increasing dietary CF level to 16% affected pig growth performance, it was beneficial for improving pork quality. Therefore, the dietary CF level for fattening Sujiang pigs can be set at 11%.

4. Conclusion

Under the conditions of this study, fattening Sujiang pigs showed excellent roughage tolerance. The appropriate dietary DE, CP and CF levels are 12.24 MJ/kg, 12% and 11%, respectively.

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