

Effects of Low Crude Protein Diets with Different Sorghum Levels on Growth Performance, Meat Quality, and Serum Amino Acid Concentrations in Growing Pigs (Postprint)

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Abstract

The objective of this experiment was to investigate the effects of low crude protein (CP) diets with different sorghum levels on growth performance, meat quality, and serum amino acid concentrations in growing pigs. Thirty-six cross-bred (Duroc × Landrace) growing pigs with a body weight of (30±7) kg were randomly allocated to 6 groups, with 6 replicates per group and 1 pig per replicate. The experimental diets contained sorghum and CP levels of 0 and 18% (Group A), 0 and 15% (Group B), 20% and 15% (Group C), 50% and 15% (Group D), 80% and 15% (Group E), and 50% and 18% (Group F), respectively. The preliminary period lasted 6 days, followed by a 35-day formal experimental period. The results showed: 1) When dietary CP level was reduced by 3%, no significant differences were observed in average daily feed intake (ADFI), average daily gain (ADG), or feed-to-gain ratio (F/G) between Groups A and B, or between Groups D and F ($P > 0.05$). At a dietary CP level of 18%, Group F had extremely significantly higher ADFI ($P < 0.01$) and significantly higher ADG ($P < 0.05$) compared with Group A. At a dietary CP level of 15%, Groups D and E had extremely significantly higher ADFI than Group B ($P < 0.01$), and Group E had significantly higher ADG than Group B ($P < 0.05$). 2) No significant differences were found in meat quality parameters among all groups ($P > 0.05$). 3) When dietary CP level was reduced by 3%, no significant differences in serum amino acid concentrations in the anterior vena cava, mesenteric vein, and portal vein were observed between Groups A and B ($P > 0.05$). At a dietary CP level of 15%, compared with Group B, the concentrations of the essential amino acid histidine in the anterior vena cava, mesenteric vein, and portal vein decreased in Groups C, D, and E, while the concentrations of the non-essential amino acids proline, serine, and alanine in the anterior vena cava increased, and the concentrations of the non-essential amino acids proline and

alanine in the mesenteric vein and portal vein increased. It can be concluded that at a dietary CP level of 15%, sorghum levels ranging from 20% to 80% can replace corn as an energy feed ingredient for growing pigs.

Full Text

Effects of Different Sorghum Levels in Low Crude Protein Diets on Growth Performance, Meat Quality, and Serum Amino Acid Concentrations in Growing Pigs

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Abstract

This experiment investigated the effects of different sorghum levels in low crude protein (CP) diets on growth performance, meat quality, and serum amino acid concentrations in growing pigs. Thirty-six crossbred (Duroc × Landrace) growing pigs with an initial body weight of (30±7) kg were randomly allocated to six groups, each consisting of six replicates with one pig per replicate. The experimental diets varied in sorghum and CP levels as follows: 0% sorghum with 18% CP (Group A), 0% sorghum with 15% CP (Group B), 20% sorghum with 15% CP (Group C), 50% sorghum with 15% CP (Group D), 80% sorghum with 15% CP (Group E), and 50% sorghum with 18% CP (Group F). The study included a 6-day adaptation period followed by a 35-day experimental period. The results revealed: (1) When dietary CP level was reduced by 3%, no significant differences were observed in average daily feed intake (ADFI), average daily gain (ADG), or feed-to-gain ratio between Groups A and B or between Groups D and F ($P > 0.05$). At 18% CP level, Group F exhibited significantly higher ADFI ($P < 0.01$) and ADG ($P < 0.05$) compared to Group A. At 15% CP level, Groups D and E showed significantly higher ADFI than Group B ($P < 0.01$), while Group E demonstrated significantly higher ADG than Group B ($P < 0.05$). (2) No significant differences in meat quality parameters were detected among any groups ($P > 0.05$). (3) When dietary CP level was reduced by 3%,

no significant differences in serum amino acid concentrations were found in the anterior vena cava, mesenteric vein, or portal vein between Groups A and B ($P > 0.05$). However, at 15% CP level, Groups C, D, and E showed decreased essential amino acid histidine concentrations in all three blood vessels compared to Group B, while non-essential amino acids proline, serine, and alanine increased in the anterior vena cava, and proline and alanine increased in the mesenteric and portal veins. These findings indicate that sorghum can effectively replace corn as an energy feed ingredient at levels of 20–80% in low-CP (15%) diets for growing pigs without adverse effects on growth performance.

Keywords: sorghum; growing pigs; growth performance; meat quality; serum amino acids

Introduction

In modern animal production, dietary crude protein (CP) level represents a critical factor for addressing both high feeding costs and nitrogen emissions. Previous research has demonstrated that supplementing diets with appropriate synthetic essential amino acids while reducing CP content does not impair animal growth performance and concurrently decreases nitrogen excretion [1]. Concurrently, as demand for cereal feed ingredients continues to grow, corn—the most common energy feed source—faces increasingly tight supply and rising prices, making the development of cost-effective alternatives imperative. Sorghum, one of the major cereal grains, serves as an excellent energy feed ingredient. Consequently, the dual strategies of reducing dietary CP levels and incorporating sorghum into animal feeds have attracted considerable attention. Studies indicate that sorghum-based diets provide comparable feeding value to corn-based diets for livestock and poultry, with sorghum's higher overall nutrient content potentially benefiting animal fattening [2]. However, different sorghum inclusion levels produce varying effects in growing pigs. Therefore, this experiment utilized growing pigs as a model to evaluate the effects of replacing corn-soybean meal with varying sorghum levels in low-CP diets on growth performance, meat quality, and serum amino acid concentrations, thereby providing a scientific basis for sorghum application in low-CP diets for growing pigs.

1.1 Experimental Design and Diets

A single-factor design was employed, utilizing 36 healthy crossbred (Duroc × Landrace) growing pigs with an initial body weight of (30 ± 7) kg. Pigs were randomly divided into six groups, each comprising six replicates with one pig per replicate. The six experimental groups received diets with varying sorghum and CP levels: 0% sorghum with 18% CP (Group A), 0% sorghum with 15% CP (Group B), 20% sorghum with 15% CP (Group C), 50% sorghum with 15%

CP (Group D), 80% sorghum with 15% CP (Group E), and 50% sorghum with 18% CP (Group F). The experimental design is summarized in .

Diets were formulated according to the nutrient requirements for growing pigs established by NRC (2012). Diet composition and nutrient levels are presented in . The feeding trial was conducted at the Animal Experimental Base of the Institute of Subtropical Agriculture, Chinese Academy of Sciences, located at Yong'an Branch of Hunan New Wufeng Co., Ltd. The study consisted of a 6-day adaptation period followed by a 35-day experimental period.

1.2 Animal Management

Prior to the experiment, all pig pens were thoroughly disinfected. At the trial's commencement, pigs were fasted, weighed, tagged, and individually housed in single pens. Pigs were fed four times daily (08:00, 10:00, 14:00, and 18:00), with feed provided ad libitum to ensure slight residual amounts remained in the trough after each feeding. Throughout the experimental period, pigs had unrestricted access to feed and water, while receiving routine immunization, deworming, and disinfection procedures.

1.3 Sample Collection and Measurements

1.3.1 Growth Performance Pigs were fasted and weighed on the morning of day 1 to determine initial body weight, and again on day 35 to determine final body weight. Average daily gain (ADG) was calculated for each group. Daily feed allowance and residual feed were recorded for each pig to calculate average daily feed intake (ADFI) and feed-to-gain ratio (F/G) for each group. Calculations were performed using the following formulas:

- Average daily gain (kg/d) = (Final body weight - Initial body weight) / Number of experimental days
- Average daily feed intake (kg/d) = Total feed intake / Number of experimental days
- Feed-to-gain ratio = Average daily feed intake / Average daily gain

1.3.2 Meat Quality Measurements Pigs were slaughtered under anesthesia (Zoletil™ 50). Meat quality parameters including muscle color [lightness (L), redness (*a*), yellowness (*b*^{*})], muscle pH (pH , pH), and shear force were measured in the longissimus dorsi muscle according to the Technical Specification for Determination of Porcine Muscle Quality (NY/T 821-2004).

1.3.3 Blood Sample Collection and Analysis Blood samples (10 mL each) were collected from the anterior vena cava, mesenteric vein, and portal vein of

each pig. Samples were centrifuged at 4,000 r/min for 10 minutes, and the separated serum was numbered, placed in ice boxes, transported to the laboratory, and stored at -80°C for subsequent analysis.

For amino acid analysis, 0.5 mL of serum sample was transferred to a 1.5 mL centrifuge tube and centrifuged at 3,000 r/min for 5 minutes. The supernatant was accurately transferred to another 1.5 mL tube, mixed with an equal volume of 10% sulfosalicylic acid, vortexed, and allowed to stand at 4°C for 1 hour. After centrifugation at 10,000 r/min for 15 minutes, the supernatant was filtered through a 0.22 μm membrane, adjusted to appropriate concentration, and analyzed using an L-8900 high-performance amino acid automatic analyzer (Hitachi, Japan).

1.4 Data Processing and Statistical Analysis

Experimental data were initially organized using Excel 2007. Statistical analysis was performed using SPSS 19.0 software with one-way ANOVA. Duncan's multiple comparison test was applied for variance analysis. All data are expressed as means \pm standard error (means \pm SE). Differences were considered significant at $P < 0.05$ and highly significant at $P < 0.01$.

Results

2.1 Effects of Different Sorghum Levels in Low-CP Diets on Growth Performance

As shown in , when dietary CP level was reduced by 3%, no significant differences in ADFI, ADG, or F/G were observed between Groups A (18% CP) and B (15% CP), or between Groups F (50% sorghum, 18% CP) and D (50% sorghum, 15% CP) ($P > 0.05$). At 18% CP level, Group F exhibited a 28.90% increase in ADFI compared to Group A ($P < 0.01$) and a 15.07% increase in ADG ($P < 0.05$), though F/G remained unchanged ($P > 0.05$). At 15% CP level, Groups D and E showed 11.05% and 20.00% increases in ADFI, respectively, compared to Group B ($P < 0.01$). Group E demonstrated an 18.67% increase in ADG compared to Group B ($P < 0.05$), while Groups C and D showed non-significant increases of 2.67% and 8.00%, respectively. Although F/G did not differ significantly among Groups B, C, D, and E ($P > 0.05$), Groups C, D, and E exhibited 2.82%, 2.01%, and 2.01% higher F/G values than Group B, respectively. Among the different sorghum level groups (C, D, and E), ADFI and ADG increased with increasing sorghum inclusion, with the 80% sorghum level (Group E) showing superior performance compared to 20% and 50% levels, warranting further investigation.

2.2 Effects of Different Sorghum Levels in Low-CP Diets on Meat Quality

As presented in , reducing dietary CP level by 3% did not significantly affect muscle pH , pH , color parameters (L, a, b*), or shear force, whether comparing Groups A and B or Groups F and D ($P > 0.05$). At 18% CP level, no significant differences in these meat quality parameters were observed between Groups A and F ($P > 0.05$). Similarly, at 15% CP level, no significant differences were detected among Groups B, C, D, and E ($P > 0.05$). However, compared to Group B, Group C (20% sorghum) showed a 4.76% increase in shear force, while Group E (80% sorghum) exhibited a 14.57% decrease. Across Groups C, D, and E, shear force tended to decrease with increasing sorghum levels, suggesting improved meat tenderness.

2.3.1 Effects on Anterior Vena Cava Serum Amino Acid Concentrations

As illustrated in , at 18% CP level, no significant differences in anterior vena cava serum amino acid concentrations were observed between Groups A and F ($P > 0.05$). When CP level was reduced by 3%, no significant differences were found between Groups A and B ($P > 0.05$). However, comparing Groups F and D (both 50% sorghum), the 3% CP reduction resulted in a 40.55% decrease in essential amino acid histidine (His) concentration ($P < 0.01$) and significant increases in non-essential amino acids proline (Pro, 17.69%), serine (Ser, 35.10%), alanine (Ala, 33.87%), and aspartic acid (Asp, 30.00%) ($P < 0.05$).

At 15% CP level, compared to Group B, Groups C, D, and E showed highly significant reductions in His concentration (19.01%, 28.93%, and 43.72%, respectively; $P < 0.01$). Lysine (Lys) concentrations increased by 18.72% (non-significant), 30.59% ($P < 0.05$), and 38.96% ($P < 0.05$) in Groups C, D, and E, respectively. Non-essential amino acids showed varying responses: Ser increased by 16.77% (non-significant), 52.70% ($P < 0.05$), and 31.39% ($P < 0.05$); Pro increased by 10.55% (non-significant), 19.69% ($P < 0.05$), and 26.53% ($P < 0.05$); glycine (Gly) increased by 10.68% (non-significant), 11.64% (non-significant), and 51.90% ($P < 0.05$); Ala increased by 7.79% (non-significant), 25.53% (non-significant), and 27.19% (non-significant); while Asp decreased by 38.33% ($P < 0.05$), 3.70% (non-significant), and 2.69% (non-significant). Among Groups C, D, and E, His concentration decreased while Lys concentration increased with rising sorghum levels. Non-essential amino acids Pro, Gly, Ala, and Asp generally increased with sorghum level, while Ser peaked at 50% sorghum inclusion.

2.3.2 Effects on Mesenteric Vein Serum Amino Acid Concentrations

As shown in , at 18% CP level, no significant differences in mesenteric vein serum amino acid concentrations were observed between Groups A and F ($P > 0.05$). Similarly, no significant differences were found between Groups A and B when CP level was reduced by 3% ($P > 0.05$). However, comparing Groups F

and D (both 50% sorghum), the 3% CP reduction led to a 28.59% decrease in His concentration ($P < 0.01$) and highly significant increases in non-essential amino acids Pro (22.91%), Ala (50.62%), and glutamic acid (Glu, 55.87%) ($P < 0.01$).

At 15% CP level, Groups C, D, and E exhibited reductions in His concentration of 19.05% (non-significant), 33.00% ($P < 0.05$), and 53.28% ($P < 0.01$), respectively, compared to Group B. Non-essential amino acids Pro and Ala increased by 10.51% (non-significant) and 20.64% (non-significant) in Group C, 17.45% ($P < 0.01$) and 46.60% ($P < 0.01$) in Group D, and 12.61% ($P < 0.01$) and 23.15% ($P < 0.01$) in Group E. Among Groups C, D, and E, His concentration decreased while Pro and Ala concentrations increased with increasing sorghum levels.

2.3.3 Effects on Portal Vein Serum Amino Acid Concentrations

As presented in , at 18% CP level, Group F showed highly significant increases in portal vein non-essential amino acids Pro (19.35%) and Ala (32.39%) compared to Group A ($P < 0.01$). When CP level was reduced by 3%, no significant differences were observed between Groups A and B ($P > 0.05$). However, comparing Groups F and D (both 50% sorghum), the 3% CP reduction resulted in a 38.49% decrease in His concentration ($P < 0.01$) and significant increases in Ala (22.39%, $P < 0.01$), Glu (49.54%, $P < 0.05$), and Pro (9.83%, $P < 0.01$).

At 15% CP level, Groups C, D, and E exhibited reductions in His concentration of 21.40% (non-significant), 30.20% (non-significant), and 49.10% ($P < 0.01$), respectively, compared to Group B. Non-essential amino acids Pro and Ala increased by 7.63% (non-significant) and 7.76% (non-significant) in Group C, 29.71% ($P < 0.01$) and 30.96% ($P < 0.01$) in Group D, and 32.94% ($P < 0.01$) and 36.45% ($P < 0.01$) in Group E. Glu decreased by 7.09% (non-significant), 23.86% (non-significant), and 43.07% ($P < 0.05$) in Groups C, D, and E, respectively. Among Groups C, D, and E, His concentration decreased while Pro, Glu, and Ala concentrations increased with rising sorghum levels.

Discussion

3.1 Effects on Growth Performance

Numerous studies have demonstrated that low-CP diets benefit both animals and the environment, with CP reductions of 2-3% having minimal impact on pig growth performance [3-7]. Our findings align with these reports, showing that a 3% CP reduction did not significantly affect growth performance in growing pigs. Sorghum, often called the “iron crop,” offers greater economic advantages than corn and wheat while thriving under broader environmental conditions, making it a cost-effective alternative that can enhance feed economics [8]. Sorghum substitution for corn in poultry and swine diets is already widespread in the

United States [9]. However, sorghum contains various anti-nutritional factors that may affect amino acid utilization, with some studies reporting adverse effects on growth performance when sorghum replaces 30% or 100% of corn [10]. Conversely, Nyannor et al. [11] found no significant differences in ileal and total tract digestibility of dry matter, energy, phosphorus, calcium, or nitrogen between sorghum-based and corn-soybean meal diets for growing pigs, suggesting sorghum can effectively replace corn. In our study, 50% and 80% sorghum levels improved ADG, while 20%, 50%, and 80% levels increased ADFI without significantly affecting F/G. Moreover, ADFI and ADG progressively improved with increasing sorghum inclusion. These results are consistent with Benz et al. [12], who reported higher ADG in sorghum-soybean meal diets compared to corn-soybean meal diets. Therefore, low-CP sorghum diets do not adversely affect growing pig performance and can be used as conventional diets.

3.2 Effects on Meat Quality

Key indicators for pork quality evaluation include pH, tenderness, and color. Post-mortem pH reflects muscle glycogenolysis rate, while color parameters (L , a , b) are assessed such that lower L , higher a , and lower b values indicate better meat color. Shear force reflects meat tenderness. Huo et al. [13] reported that dietary CP level did not significantly affect muscle pH or color, findings consistent with our results. Different sorghum levels in low-CP diets did not significantly influence pH, L , a , b^* values, or shear force in the longissimus dorsi muscle. Notably, all groups exhibited relatively high pH values (6.5–6.7), possibly due to stress-induced glycogen depletion during slaughter. Shear force varied with sorghum level at 15% CP: 20% sorghum increased shear force, 50% sorghum showed minimal effect, while 80% sorghum decreased shear force by 14.57% compared to Group B. This trend toward reduced shear force with higher sorghum inclusion suggests improved meat tenderness.

3.3 Effects on Serum Amino Acid Concentrations

Amino acids are fundamental protein constituents that play crucial roles in animal growth, development, and metabolism. Previous research has established relationships between amino acid requirements and blood free amino acid concentrations [14], with postprandial accumulation of blood free amino acids well-documented [15]. Serum amino acid concentrations provide important insights into amino acid balance patterns. Our results demonstrate that different sorghum levels in low-CP diets affect serum amino acid profiles to varying degrees. In anterior vena cava serum, Asp concentration decreased, most notably at 20% sorghum, while Ser and Gly concentrations increased with sorghum level. In mesenteric and portal veins, His concentration decreased with increasing sorghum, whereas Ala and Pro concentrations increased. In mesenteric vein, Ala and Pro increases were greatest at 50% sorghum, while Glu elevation occurred only at 50% and 80% sorghum levels.

Histidine has been shown to alleviate oxidative stress and enhance antioxi-

dant capacity [16], while Asp affects daily gain and intestinal mucosal integrity through lipopolysaccharide pathways [17,18]. Despite reductions in His and Asp concentrations, no adverse effects on growth performance were observed, suggesting potentially improved amino acid utilization. Glycine influences immune regulation and inflammatory responses, thereby reducing infectious disease susceptibility. Serine affects one-carbon metabolism, and D-serine modulates N-methyl-D-aspartate (NMDA) receptors in the brain [19]. Wu [20] reported that proline affects immune function and plays important roles in pig growth and development. Alanine directly influences transamination and inter-organ carbon/nitrogen metabolism and transport. Approximately 90% of dietary glutamate is extensively metabolized in the small intestine, with only a small portion entering the portal vein, serving as a primary energy source for intestinal tissue [21-23]. Elevations in these amino acids likely benefit animal growth and development. Our findings suggest that reduced serum free amino acid concentrations may reflect enhanced utilization efficiency, though the underlying mechanisms require further investigation.

Conclusion

1. Low-CP diets with different sorghum levels did not adversely affect growth performance in growing pigs. However, 50% sorghum inclusion reduced essential amino acid histidine concentrations in anterior vena cava, mesenteric vein, and portal vein serum, while affecting non-essential amino acids proline, serine, alanine, and aspartic acid in anterior vena cava, and proline, alanine, and glutamic acid in mesenteric and portal veins.
2. At 15% dietary CP level, sorghum inclusion at 20%, 50%, and 80% did not negatively impact growth performance. Therefore, reducing dietary CP by 3% and incorporating sorghum at 20-80% can be practically applied in swine production.

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