Effects of Dietary Leucine and Glutamic Acid Supplementation on Growth Performance, Carcass Traits, and Meat Quality in Finishing Pigs (Postprint)

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Abstract

This study aimed to investigate the effects of dietary leucine and glutamate supplementation on growth performance, carcass traits, and meat quality in finishing pigs. Sixty "Duroc × Landrace × Yorkshire" finishing pigs with an initial body weight of approximately 77 kg were randomly allocated into 5 groups (n = 12 per group), with equal numbers of barrows and gilts. The control group was fed a basal diet, while the experimental groups were fed the basal diet supplemented with 2.05% L-alanine (isonitrogenous control group), 1% leucine + 1.37% L-alanine (leucine group), 1% glutamate + 1.44% L-alanine (glutamate group), or 1% leucine + 1% glutamate (leucine + glutamate group). The experimental period lasted 60 days. The results showed that, compared with the control group, the glutamate group exhibited significantly reduced average daily feed intake, final body weight, and backfat thickness during days 1-30 ($P<0.05$), and a 22.5% reduction in average daily gain during days 31-60 ($P>0.05$). The leucine and leucine + glutamate groups showed significantly increased intramuscular fat content in the longissimus dorsi and biceps femoris muscles ($P<0.05$), and the leucine + glutamate group had an 8.04% increase in average daily gain during days 1-30 ($P>0.05$) but a 23.70% decrease during days 31-60 ($P>0.05$). Compared with the isonitrogenous control group, the leucine and glutamate groups showed no significant differences in cooking loss, drip loss, or meat color ($P>0.05$), while the leucine + glutamate group exhibited significantly reduced muscle yellowness (b*) values ($P<0.05$). No significant differences were observed in flavor amino acid content in the longissimus dorsi and biceps femoris muscles among any experimental groups ($P>0.05$). These results suggest that dietary supplementation with 1% leucine can reduce the feed-to-gain ratio and increase intramuscular fat content in the longissimus dorsi of finishing pigs during days

1-30; dietary supplementation with 1% glutamate or 1% leucine + 1% glutamate can increase average daily gain during days 1-30 but decrease it during days 31-60; and dietary supplementation with 1% leucine + 1% glutamate can reduce meat yellowness values and increase intramuscular fat content, thereby improving pork quality.

Full Text

Effects of Dietary Leucine and Glutamate on Growth Performance, Carcass Traits and Meat Quality of Finishing Pigs

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Abstract: This study investigated the effects of dietary leucine and glutamate supplementation on growth performance, carcass traits, and meat quality in finishing pigs. Sixty Duroc × Large White × Landrace finishing pigs (approximately 77 kg body weight) were randomly allocated to five groups (n = 12 per group, half male and half female). The control group received a basal diet, while experimental groups received the basal diet supplemented with: 2.05% L-alanine (iso-nitrogenous control), 1% leucine + 1.37% L-alanine (leucine group), 1% glutamate + 1.44% L-alanine (glutamate group), or 1% leucine + 1% glutamate (leucine + glutamate group). The 60-day trial revealed that, compared with the control group, the glutamate group exhibited significantly reduced average daily feed intake during days 1-30, final body weight, and backfat thickness ($P < 0.05$), while average daily gain during days 31-60 decreased by 22.5% ($P > 0.05$). Both leucine and leucine + glutamate groups showed significantly elevated intramuscular fat content in the longissimus dorsi and biceps femoris muscles ($P < 0.05$). The leucine + glutamate group demonstrated an 8.04% increase in average daily gain during days 1-30 ($P > 0.05$) but a 23.70% reduction during days 31-60 ($P > 0.05$). Compared with the iso-nitrogenous control, leucine and glutamate groups showed no significant differences in cooking loss, drip loss, or meat color ($P > 0.05$), whereas the leucine + glutamate group exhibited significantly lower meat yellowness values ($P < 0.05$). No significant differences in flavor amino acid content were observed in either muscle across all treatment groups ($P > 0.05$). These results suggest that dietary supplementation with 1% leucine reduces feed-to-gain ratio during days 1-30 and increases intramuscular fat deposition in the longissimus dorsi muscle. Supplementation

with 1% glutamate or the combination of 1% leucine + 1% glutamate increases average daily gain during the early phase but decreases it during the later phase. The combined supplementation of 1% leucine + 1% glutamate reduces meat yellowness values and enhances intramuscular fat content, thereby improving pork quality.

Keywords: leucine; glutamate; finishing pigs; growth performance; meat quality

Introduction

With rising living standards, consumers increasingly demand higher pork quality and flavor. Intramuscular fat (IMF) represents one of the most critical factors in sensory and physicochemical meat quality evaluation. Moderate IMF content (2–3%) with uniform distribution enhances meat flavor, juiciness, and palatability [1]. While advances in genetic breeding and feed formulation have improved growth rate, feed conversion efficiency, and lean meat percentage, they have also led to excessive subcutaneous and visceral fat deposition, reduced IMF content, and deteriorated carcass quality. Consequently, developing green and efficient functional feed additives tailored to porcine metabolic characteristics and nutritional requirements has become essential for high-quality pork production [2]. Recent years have witnessed the emergence of the "functional amino acid" concept, prompting extensive research into their physiological functions [3].

Emerging evidence demonstrates that glutamate and leucine serve not only as protein synthesis precursors but also possess diverse physiological functions. Glutamate reduces body fat deposition [4], decreases muscle fiber diameter, increases inosine monophosphate content, and alters muscle fatty acid composition [5–6]. Dietary supplementation with 1% glutamate has proven safe and can improve feed conversion efficiency in pigs [7]. Leucine activates the mammalian target of rapamycin complex 1 (mTORC1) signaling pathway to promote protein synthesis, increase lean meat percentage [8], inhibit adipocyte fatty acid synthase expression, and reduce triglyceride content [9]. Studies have shown that 1% leucine supplementation enhances weight gain [10]. However, other research indicates that while leucine or glutamate supplementation may increase IMF content, it does not significantly affect growth performance or carcass traits [6, 11]. Although numerous studies have investigated the regulation of animal growth and meat quality by leucine and glutamate, few have examined the effects of simultaneous supplementation of both amino acids in finishing pigs. Therefore, this study aimed to evaluate the effects of dietary supplementation with 1% leucine and/or 1% glutamate on growth performance, carcass traits, and meat quality to provide a basis for improving pork quality in swine production.

1.1 Experimental Animals, Grouping, and Management

Sixty Duroc × Large White × Landrace finishing pigs (approximately 77 kg body weight) were randomly assigned to five groups (n = 12 per group, half male and half female) and housed in an HHIS-02A automatic feeding system (Henan Heshun Automation Equipment Co., Ltd.). The control group received a basal diet. L-alanine was used to regulate dietary nitrogen balance [12–13]; thus, the iso-nitrogenous control group received the basal diet supplemented with 2.05% L-alanine. Experimental groups received the basal diet supplemented with: 1% leucine + 1.37% L-alanine (leucine group), 1% glutamate + 1.44% L-alanine (glutamate group), or 1% leucine + 1% glutamate (leucine + glutamate group).

A corn-soybean meal basal diet was formulated according to NRC (2012) nutrient requirements. Diet composition and nutrient levels are presented in Table 1 . 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 Xinwufeng Co., Ltd. The 60-day trial allowed ad libitum access to feed and water, with routine immunization protocols maintained.

1.2 Growth Performance Measurement

Daily feed intake and body weight gain were recorded throughout the trial to calculate average daily feed intake (ADFI), average daily gain (ADG), and feed-to-gain ratio (F/G) for days 1–30 and 31–60.

1.3 Carcass Trait Measurement

At trial conclusion, pigs were fast-weighed and slaughtered according to the National Standard "Operating Procedures of Pig Slaughtering." After exsanguination via carotid artery, heads, hooves, tails, and viscera were removed while leaf fat and kidneys were retained. Carcass weight was recorded to calculate dressing percentage. Backfat thickness was measured at the 6th–7th rib interface using vernier calipers. After dissection, lean meat, fat, skin, and bone were weighed separately to calculate lean percentage, fat percentage, skin percentage, and bone percentage [14].

1.4 Meat Quality Measurement

Longissimus dorsi samples were collected to determine drip loss and cooking loss. Meat color values were measured within 2 hours postmortem using a Minolta Chroma Meter . Freeze-dried and pulverized longissimus dorsi and biceps femoris samples were analyzed for crude protein, crude fat, dry matter, and amino acid content using conventional methods [15–16].

1.5 Statistical Analysis

Data were analyzed using SPSS 17.0 software with Duncan' s multiple comparison test. Results are expressed as "mean ± standard error." $P < 0.05$ was

considered statistically significant.

2.1 Effects of Dietary Leucine and Glutamate on Growth Performance

As shown in Table 2 , compared with the control group, the leucine group exhibited significantly reduced F/G during days 1-30 ($P < 0.05$). The glutamate group showed significantly lower ADFI and F/G during days 1-30 ($P < 0.05$). The leucine + glutamate group demonstrated no significant differences in ADG or ADFI during days 1-30 ($P > 0.05$) but had significantly reduced F/G ($P < 0.05$). Compared with the iso-nitrogenous control, the leucine group showed significantly lower F/G during days 1-30 ($P < 0.05$), the glutamate group exhibited significantly reduced F/G during days 1-30 and ADFI during days 31-60 ($P < 0.05$), and the leucine + glutamate group had significantly lower F/G during days 1-30 ($P < 0.05$).

2.2 Effects of Dietary Leucine and Glutamate on Carcass Traits

Table 3 shows that compared with the control group, the glutamate group had significantly reduced backfat thickness ($P < 0.05$), while leucine and leucine + glutamate groups showed no significant differences in carcass quality ($P > 0.05$). Compared with the iso-nitrogenous control, the leucine group exhibited significantly increased dressing percentage ($P < 0.05$), while glutamate and leucine + glutamate groups showed no significant differences in carcass quality ($P > 0.05$).

2.3 Effects of Dietary Leucine and Glutamate on Meat Quality

As shown in Table 4 , compared with the control group, leucine, glutamate, and leucine + glutamate groups showed no significant differences in cooking loss, drip loss, or meat color ($P > 0.05$). Compared with the iso-nitrogenous control, leucine and glutamate groups also showed no significant differences in these parameters ($P > 0.05$), while the leucine + glutamate group exhibited significantly lower meat yellowness values ($P < 0.05$) without affecting cooking loss or drip loss ($P > 0.05$).

2.4 Effects of Dietary Leucine and Glutamate on Muscle Nutrient Composition

Table 5 demonstrates that compared with the control group, leucine and leucine + glutamate groups showed significantly increased intramuscular fat content in both longissimus dorsi and biceps femoris muscles ($P < 0.05$), while the glutamate group exhibited significantly increased intramuscular fat in biceps femoris muscle ($P < 0.05$). Compared with the iso-nitrogenous control, the leucine group showed significantly increased intramuscular fat in longissimus dorsi muscle ($P < 0.05$). The glutamate group showed no significant differences in dry matter, intramuscular fat, or crude protein content in either muscle ($P > 0.05$).

The leucine + glutamate group exhibited significantly increased intramuscular fat content in longissimus dorsi muscle ($P < 0.05$).

2.5 Effects of Dietary Leucine and Glutamate on Flavor Amino Acid Content

No significant changes were observed in aspartic acid, glutamate, glycine, alanine, methionine, or proline content in longissimus dorsi or biceps femoris muscles across all groups compared with the control group ($P > 0.05$, data not shown).

Discussion

Leucine and glutamate are essential amino acids in humans and animals. Beyond protein synthesis, leucine activates the mammalian target of rapamycin (mTOR) signaling pathway to promote protein synthesis, maintain muscle mass, inhibit fat synthesis, enhance lipolysis, and increase energy expenditure [17]. In this study, dietary leucine supplementation significantly reduced the feed-to-gain ratio during the early finishing period (days 1–30) without significantly affecting other growth performance indices, consistent with Madeira et al. [18]. Similar studies have reported that leucine supplementation does not significantly affect feed intake or body weight in C57BL/6 mice [19]. Dietary glutamate supplementation in this study increased ADG during the early phase but decreased it during the later phase (days 31–60), resulting in significantly reduced final body weight due to decreased feed intake. Feed intake is a crucial factor limiting animal growth performance. As a neurotransmitter in the central nervous system, glutamate regulates feed intake and body weight through neural activity [20–21]. Studies have shown that glutamate injection reduces animal feed intake [22], aligning with our findings. However, other research indicates that dietary glutamate supplementation does not significantly affect finishing pig growth performance [23]. These discrepancies may stem from differences in experimental diets and glutamate supplementation levels. When leucine and glutamate were supplemented simultaneously, growth performance mirrored that of glutamate supplementation alone, suggesting that leucine could not counteract the negative effects of glutamate on growth performance during the later phase. The ideal amino acid pattern (IAAP) is a key technology for formulating low-protein diets for pigs. Research indicates that pigs have different amino acid balance patterns for various production purposes [24], and reducing dietary protein level while supplementing amino acids to achieve IAAP does not affect nitrogen deposition [25]. In this study, supplementing leucine and/or glutamate to a low-protein diet altered the ratio of these amino acids relative to lysine, which may explain the observed changes in growth performance, though further analysis is needed.

Dressing percentage, lean percentage, fat percentage, backfat thickness, and bone percentage reflect carcass quality. Backfat thickness primarily indicates fat deposition capacity and serves as a production metric for lean percentage. This

study found that 1% glutamate supplementation significantly reduced backfat thickness, suggesting that glutamate can improve carcass quality by reducing fat deposition.

Meat quality evaluation includes cooking loss, drip loss, and meat color. Water-holding capacity affects juiciness, aroma, and taste, while meat color is an important visual quality indicator for consumers [26]. Dietary leucine or glutamate supplementation alone did not significantly affect these parameters in this study. Madeira et al. [18] reported that leucine supplementation did not alter cooking loss or meat color. Chun et al. [27] found that monosodium glutamate reduced water-holding capacity without affecting cooking loss. Combined leucine and glutamate supplementation did not affect cooking loss or drip loss but significantly reduced meat yellowness values, indicating synergistic effects on meat color improvement.

Intramuscular fat content is closely associated with pork tenderness, juiciness, and flavor. This study demonstrated that leucine supplementation significantly increased intramuscular fat content in both longissimus dorsi and biceps femoris muscles, consistent with Madeira et al. [18]. Combined leucine and glutamate supplementation significantly increased intramuscular fat content in the longissimus dorsi muscle, thereby improving pork quality. Intramuscular fat content negatively correlates with lean percentage, while backfat thickness positively correlates with fat percentage and negatively correlates with lean percentage. Although modern biotechnology has improved lean percentage and reduced backfat thickness, it has also decreased intramuscular fat content, compromising meat quality. Our results indicate that combined leucine and glutamate supplementation, while potentially reducing some carcass traits compared with individual supplementation, improves meat quality by increasing intramuscular fat content. Flavor amino acid content is an important indicator of pork flavor and umami taste. Previous studies have shown that glutamate and aspartate enhance umami flavor, while glycine and alanine increase sweetness [29]. However, this study found that leucine and glutamate supplementation did not increase flavor amino acid content in muscle.

Conclusions

1. Dietary supplementation with 1% leucine reduces the feed-to-gain ratio during days 1–30 and increases intramuscular fat content in the longissimus dorsi muscle of finishing pigs.
2. Dietary supplementation with 1% glutamate or 1% leucine + 1% glutamate increases average daily gain during days 1–30 but decreases it during days 31–60.
3. Dietary supplementation with 1% leucine + 1% glutamate reduces meat yellowness values and increases intramuscular fat content, thereby improving pork quality.

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