# Effects of Multi-Nutrient Source Diets on Growth Performance, Apparent Nutrient Digestibility, and Meat Quality in Growing-Finishing Pigs (Postprint)

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## Abstract

The present study aimed to investigate the effects of nutrient-source diets on growth performance, nutrient apparent digestibility, and meat quality of growing-finishing pigs, and to explore the feasibility of formulating diets using unconventional feed ingredients. Forty-eight Duroc × Landrace × Yorkshire growing pigs with similar age and body weight of (41.06$±$1.43) kg were randomly allocated to 2 groups, and fed a corn-soybean meal basal diet (control group) and a multi-nutrient source diet (experimental group), respectively. The growth phase lasted 42 days; during the finishing phase, when pigs reached 120 kg body weight, 5 pigs per group were selected for slaughter and meat quality determination. The results showed that: 1) compared with the control group, the average daily feed intake of pigs in the experimental group increased by 7.76% (P>0.05), while no significant differences were observed in average daily gain, feed-to-gain ratio, and energy intake (P>0.05); 2) compared with the control group, the apparent digestibility of calcium, phosphorus, energy, crude protein, crude ash, and dry matter in the experimental group was significantly decreased (P<0.05), while the apparent digestibility of crude fat showed no significant difference (P>0.05); 3) compared with the control group, feeding the multi-nutrient source diet significantly increased the activity of serum alanine aminotransferase in experimental pigs (P<0.05), but had no significant effect on other serum biochemical parameters (P>0.05); 4) compared with the control group, feeding the multi-nutrient source diet had no significant effect on pork quality and the intramuscular fat and protein contents of longissimus dorsi muscle (P>0.05). It can be concluded that under the conditions of this experiment, feeding a multi-nutrient source diet primarily composed of unconventional feed ingredients decreased the nutrient apparent digestibility of

growing-finishing pigs, but had no negative effects on their growth performance and meat quality.

## Full Text

# Effects of Multi-Nutrient Source Diet on Growth Performance, Apparent Nutrient Digestibility and Meat Quality of Growing-Finishing Pigs

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**Abstract:** This experiment was conducted to investigate the effects of multi-nutrient source diets on growth performance, apparent nutrient digestibility, and meat quality of growing-finishing pigs, and to explore the feasibility of using unconventional feed ingredients in diet formulation. Forty-eight "Duroc × Landrace × Yorkshire" growing pigs with similar age and initial body weight of (41.06 ± 1.43) kg were randomly allocated to two groups, fed either a corn-soybean meal basal diet (control group) or a multi-nutrient source diet (experimental group). The growing stage lasted for 42 days. During the finishing stage, when pigs reached 120 kg body weight, five pigs from each group were selected for slaughter and meat quality evaluation. The results showed that: 1) Compared with the control group, the average daily feed intake of pigs in the experimental group increased by 7.76% ($P > 0.05$), with no significant differences in average daily gain, feed-to-gain ratio, or energy intake ($P > 0.05$); 2) The apparent digestibility of calcium, phosphorus, energy, crude protein, crude ash, and dry matter in the experimental group was significantly lower than that in the control group ($P < 0.05$), while ether extract digestibility showed no significant difference ($P > 0.05$); 3) Feeding the multi-nutrient source diet significantly increased serum alanine aminotransferase activity ($P < 0.05$) but had no significant effects on other serum biochemical indices ($P > 0.05$); 4) The multi-nutrient source diet had no significant effects on pork quality or intramuscular fat and protein content in the longissimus dorsi muscle ($P > 0.05$). In conclusion, under the conditions of this experiment, feeding a multi-nutrient source diet based primarily on unconventional feed ingredients reduced apparent nutrient digestibility in growing-finishing pigs but did not negatively affect growth performance or meat quality.

**Keywords:** nutrient source; growth performance; apparent nutrient digestibility; meat quality

## Introduction

Modern animal nutrition science has developed for over 200 years, gradually unveiling the mystery of required nutrients for animals, including their types, functions, and requirements, which has led to the establishment of animal nutrient requirement standards. However, practical production and numerous animal experiments have shown that feeding diets formulated with the same nutritional standards but different nutrient sources yields vastly different results, indicating that the connotation of animal nutrition cannot be fully explained by nutrients and nutrient levels alone. Consequently, scientists have proposed the concept of "nutritional structure," which emphasizes the balance of nutrients, the balance of nutrient sources, their interrelationships, and relationships with growth-promoting factors. This study primarily investigates nutrient sources and their interactions. In current feed production, to ensure effectiveness and production convenience, feeds are often formulated with simple corn-soybean meal based recipes, resulting in large consumption of high-quality feed ingredients like corn and soybean meal that domestic production often struggles to meet. Meanwhile, abundant grain processing by-products in China are underutilized in the feed industry, causing tremendous waste of feed resources. To avoid competition for grain between humans and livestock, increasing the application of grain processing by-products in feed is crucial. Previous research has demonstrated that using unconventional nutrient sources to replace corn and soybean meal within certain limits does not negatively affect pig performance. For instance, Apple et al. found that replacing soybean meal with 3% hydrolyzed feather meal caused no significant changes in animal performance, and Huang et al. reported that adding 20% sorghum and 10% dried distillers grains with solubles (DDGS) to growing pig diets resulted in growth performance comparable to the corn-based group. Nevertheless, determining appropriate inclusion levels and developing more nutrient source combinations require further analysis and experimentation. Therefore, this study aimed to investigate the effects of multi-nutrient source diets on growth performance, apparent nutrient digestibility, and meat quality of growing-finishing pigs, to evaluate their application value in utilizing unconventional ingredients, reducing feed costs, and improving production efficiency.

### 1.1 Experimental Materials

Feed ingredients used in this experiment included corn germ meal, wheat, DDGS, and cottonseed meal purchased from Pengshan Qinglongchang Raw Material Wholesale Market in Meishan City, Sichuan Province; hulled barley and rapeseed meal from Sichuan Tieqi Lishi Group; and flaxseed meal and peanut meal from Heze, Shandong and Zhumadian, Henan, respectively.

### 1.2 Experimental Animals and Design

Forty-eight "Duroc × Landrace × Yorkshire" growing pigs with initial body weight of (41.06 ± 1.43) kg were randomly allocated to two groups, each with

12 replicates (pens) of two pigs. The control group was fed a corn-soybean meal basal diet, while the experimental group received a multi-nutrient source diet with lower energy content. The growing stage lasted 42 days. During days 32–35, an endogenous indicator method was used for digestibility trials. On day 43, one pig per replicate was selected for blood collection, and all pigs were weighed. During the finishing stage, pigs were continuously fed until reaching 120 kg body weight, at which point five pigs per group were selected for slaughter and meat quality determination.

### 1.3 Experimental Diets

Diets were formulated according to NRC (2012) nutrient requirements for 50–75 kg and 75–120 kg pigs. The basal diet was corn-soybean meal based, while the multi-nutrient source diet was formulated by combining various energy and protein sources. Diet composition and nutrient levels are presented in .

### 1.4 Feeding Management

The experiment was conducted at the Teaching and Research Farm of the Institute of Animal Nutrition, Sichuan Agricultural University. After a 5-day adaptation period, the formal experiment began. Pigs were fed three times daily (08:00, 13:30, and 19:00) with small amounts given multiple times until a small amount remained after ad libitum feeding. Pigs had free access to drinking water, and pen temperature was maintained at approximately 21 °C.

### 1.5 Slaughter and Tissue Sampling

Pigs weighing approximately 120 kg were selected for slaughter. The left carcass side was separated to sample the longissimus dorsi muscle. The muscle at the 1st–2nd ribs from the lumbosacral junction was used for pH and meat color determination, the 3rd–4th ribs for drip loss and cooking loss measurement, and the 5th–6th ribs for intramuscular fat and protein content analysis.

### 1.6 Measurement Indicators

**1.6.1 Growth Performance** Pigs were weighed on an empty stomach on days 1 and 43 of the experiment by pen. Daily feed intake per pen was recorded throughout the trial to calculate average daily feed intake (ADFI), average daily gain (ADG), and feed-to-gain ratio (F/G).

**1.6.2 Apparent Nutrient Digestibility** The content of various nutrients in feces and diets, as well as the endogenous indicator (acid-insoluble ash), were determined to calculate apparent digestibility. Energy was measured using an automatic oxygen bomb calorimeter (PARR 6400, USA); crude protein using an automatic Kjeldahl nitrogen analyzer (BUCHI K-360, Switzerland); acid-insoluble ash according to GB/T 23742–2009/ISO 5985:2002; and crude ash, calcium, phosphorus, and dry matter according to methods described by Zhang

(2007). Apparent digestibility of each nutrient (%) was calculated as: 100 -100 × (A/A1) × (B1/B), where A is the nutrient content per kg of feces, A1 is the nutrient content per kg of diet, B is the acid-insoluble ash content per kg of feces, and B1 is the acid-insoluble ash content per kg of diet.

**1.6.3 Serum Biochemical Indices** Serum glucose (GLU), urea nitrogen (UN), triglyceride (TG) concentrations, and alkaline phosphatase (AKP), aspartate aminotransferase (AST), and alanine aminotransferase (ALT) activities were determined using an automatic blood biochemical analyzer (Hitachi 7020, Japan).

**1.6.4 Meat Quality** Meat quality was determined according to NY/T 1333 –2007 "Methods for Detection of Livestock and Poultry Meat Quality" and methods described by Yan (2013).

### 1.7 Statistical Analysis

Experimental data were organized using Microsoft Excel 2007 and analyzed by t-test using SPSS 19.0 statistical software. Differences were considered significant at $P < 0.05$.

## Results

### 2.1 Effects of Multi-Nutrient Source Diet on Growth Performance of Growing-Finishing Pigs

As shown in , compared with the control group, ADFI of growing-finishing pigs in the experimental group increased by 7.76% ($P > 0.05$), with no significant differences observed in ADG, F/G, or digestible and net energy intake between the two groups ($P > 0.05$).

### 2.2 Effects of Multi-Nutrient Source Diet on Apparent Nutrient Digestibility of Growing-Finishing Pigs

As shown in , apparent digestibility of calcium, phosphorus, energy, crude protein, crude ash, and dry matter in the experimental group was significantly lower than in the control group ($P < 0.05$), while ether extract digestibility showed no significant difference between groups ($P > 0.05$).

### 2.3 Effects of Multi-Nutrient Source Diet on Serum Biochemical Indices of Growing-Finishing Pigs

As shown in , feeding the multi-nutrient source diet significantly increased serum ALT activity ($P < 0.05$) but had no significant effects on other serum biochemical indices ($P > 0.05$).

### 2.4 Effects of Multi-Nutrient Source Diet on Meat Quality of Growing-Finishing Pigs

As shown in , the multi-nutrient source diet had no significant effects on muscle quality or intramuscular fat and protein content in the longissimus dorsi muscle ($P > 0.05$).

## Discussion

The main factors affecting pig growth performance are feed intake and the efficiency of nutrient digestion and utilization. Among the many factors influencing feed intake, diet composition is one of the most important. Pigs possess numerous taste buds and have sensitive taste perception, and diet palatability can be modulated to affect feed intake. Rapeseed meal contains isothiocyanates that produce a bitter taste and severely affect palatability; research has shown that adding 5% rapeseed meal to finishing pig diets reduces feed intake. In this experiment, however, the inclusion levels of rapeseed meal and other miscellaneous meals were 1.5% or less, thus causing no negative effects on feed intake. Dietary energy level is another critical factor affecting feed intake; when dietary energy is low, pigs compensate by increasing feed intake to obtain sufficient energy. Qiao (2006) demonstrated that adding 10% and 20% wheat bran to normal-energy diets to dilute energy content increased both ADG and ADFI compared with the control group. Therefore, both energy level and nutrient source influence feed intake.

The lower apparent nutrient digestibility observed in the multi-nutrient source diet group can be attributed to the presence of various anti-nutritional factors. Ou (2004) reported that high $\beta$-glucan content in barley increases chyme viscosity, resulting in inadequate contact between chyme and digestive enzymes and consequently lower nutrient digestibility, which can be improved by adding exogenous enzymes. Increased dietary fiber content can raise chyme viscosity and accelerate intestinal transit, thereby reducing nutrient digestibility. Wilfart et al. (2007) showed that adding 0%, 20%, and 40% wheat bran to growing pig diets to increase fiber content progressively elevated fecal concentrations of crude protein, ether extract, fiber, and organic matter. Phytic acid in diets has strong metal-chelating ability, forming insoluble phytate salts in the gastrointestinal tract that reduce mineral utilization, and its phosphate groups can bind proteins to form binary complexes that precipitate proteins and decrease protein utilization. Sun (2009) found that adding 1,000 mg/kg phytase to diets containing rapeseed or cottonseed meal significantly improved crude protein, calcium, and phosphorus digestibility but had no significant effects on gross energy or dry matter digestibility. The multi-nutrient source diet in this experiment contained higher levels of phytate phosphorus from miscellaneous meals, increased crude fiber from barley and wheat bran, and other factors such as barley $\beta$-glucan and wheat gliadin, all contributing to lower apparent nutrient digestibility.

Despite similar dietary nutrient levels, the multi-nutrient source diet group main-

tained growth performance comparable to the control group despite lower apparent digestibility and no significant difference in feed intake. This may be explained by several mechanisms. First, although apparent digestibility decreased, pigs may have regulated endogenous excretion to improve true digestibility. Zuo (2005) demonstrated that in barley/soybean meal diets, apparent phosphorus digestibility increased rapidly with dietary total phosphorus content before plateauing, while true digestibility was unaffected by dietary phosphorus level, indicating that pigs can adapt to different nutrient levels through endogenous excretion. Second, dietary energy sources providing sustained glucose supply to the intestine can reduce amino acid oxidation for energy, thereby increasing portal vein amino acid content; compared with lactose, corn starch energy significantly reduced portal vein total amino acid content. The multi-nutrient source diet may have provided slower, more sustained glucose release, reducing amino acid oxidation in the intestine. Third, volatile fatty acids (VFAs) produced by microbial fermentation of indigestible resistant starch and crude fiber in the hindgut may have contributed to energy supply. VFAs, primarily acetate, propionate, and butyrate, serve as energy sources: butyrate fuels intestinal cells and promotes VFA absorption, acetate is oxidized in the liver to provide energy for peripheral tissues, and propionate inhibits cholesterol and fatty acid synthesis. Thus, the multi-nutrient source diet may have maintained growth performance through increased VFA supply. This suggests that diets must provide not only nutrients for eukaryotic cells but also energy for abundant prokaryotic microbes, and that optimal feed efficiency requires reasonable combinations of miscellaneous ingredients to meet both host and microbial nutritional needs rather than simply pursuing high digestibility.

Serum GLU, TG, and UN concentrations reflect metabolism of the three major nutrients. GLU is the primary energy-supplying nutrient, and Chao (2009) found that blood glucose increases with dietary energy concentration. Serum UN, the main end product of protein and amino acid metabolism in mammals, represents amino acids not utilized for protein synthesis, and its concentration accurately reflects protein metabolism and amino acid balance, with lower UN indicating better amino acid balance. Xia (2014) reported that adding 17% DDGS did not significantly affect serum UN compared with the soybean meal group, whereas casein addition significantly reduced UN, suggesting that highly digestible protein can significantly decrease serum UN. TG is the main form of fat deposition, derived from dietary intake and hepatic synthesis, and high serum TG may reflect increased hepatic fat synthesis, though this experiment showed no significant differences between groups. Clinically, AST and ALT are considered liver damage markers, but studies indicate they lack organ specificity in pigs and can serve as reference indices for protein metabolism. Shi (2015) found that replacing soybean meal with 10% unfermented rapeseed meal significantly increased serum AST activity and UN concentration, whereas fermented rapeseed meal had no significant effects, indicating that unfermented rapeseed meal reduces hepatic protein synthesis capacity while fermented rapeseed meal provides higher-quality protein. Numerous studies have demonstrated that AKP

is significantly positively correlated with ADG, as AKP catalyzes hydrolysis of phosphorylated compounds during metabolism, accelerating metabolic processes and improving growth performance, consistent with findings in ducks and pigs.

Conventional meat quality indices include pH at 45 min and 24 h postmortem, meat color, drip loss, cooking loss, and shear force, with nutritional regulation being the primary means of improvement. Rong (2012) used peanut vine powder to replace wheat bran at different ratios to increase dietary fiber, finding that drip loss in Huai pigs first increased then decreased with increasing fiber content, peaking at a 1:1 ratio and significantly exceeding the wheat bran-only control group, while muscle protein content increased with fiber content, possibly due to different fiber metabolism between Huai and DLY pigs. Chen et al. (2002) reported that low metabolizable energy (12 MJ/kg) significantly reduced lean percentage and intramuscular fat content compared with high energy (14 MJ/kg) at 80 and 100 kg body weight stages. In this experiment, the lower-energy experimental group did not show significantly increased intramuscular fat, likely because the dietary energy difference between groups was only 0.88 MJ/kg with no significant difference in net energy intake, insufficient to affect intramuscular fat content.

## Conclusion

Under the conditions of this experiment, the multi-nutrient source diet significantly reduced apparent nutrient digestibility in growing pigs but had no significant effects on growth performance or meat quality.

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