Effects of Different Protein Source Combinations on Growth Performance and Serum Biochemical Parameters in Nursery Pigs: Postprint

Authors: Li Yunhu, Liao Peng, Tang Wei, Rejun Fang, Deng Zaofu, Li Wei, Li Meijun

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Abstract

In this experiment, fish meal, plasma protein powder, yeast powder, and intestinal mucosa protein powder were combined at specific proportions and added to the diet to comparatively investigate the effects of different protein source combinations on growth performance and serum biochemical indices of nursery pigs. A total of 108 three-way crossbred (Duroc × Landrace × Yorkshire) nursery pigs with an initial body weight of (6.36±0.20) kg were selected and randomly allocated into 3 groups, with 6 replicates per group and 6 pigs per replicate. The three groups of nursery pigs were fed diets containing 1.5% plasma protein powder + 2.0% fish meal (Group A, serving as the control group), 3.0% intestinal mucosa protein powder + 5.0% fish meal (Group B), and 2.0% yeast powder + 2.0% intestinal mucosa protein powder + 2.0% fish meal (Group C), respectively, with a 3-day preliminary period and a 14-day formal experimental period. The results showed: 1) The average daily feed intake and average daily gain of Group B were significantly lower than those of Group A and Group C ($P < 0.05$). Compared with Group A, the average daily feed intake and average daily gain of Group C increased by 1.76% and 8.13%, respectively, but the differences were not significant ($P > 0.05$). Regarding feed-to-gain ratio, no significant differences were observed between Groups B and C compared with control Group A ($P > 0.05$), but Group C was significantly lower than Group B ($P < 0.05$). 2) No significant differences were detected among the three groups in serum total protein, albumin, globulin, urea nitrogen content, albumin-to-globulin ratio, or the activities of alanine aminotransferase and aspartate aminotransferase ($P > 0.05$). 3) Compared with Group A, the cost per kilogram gain of Group B increased by 13.47% ($P > 0.05$), while that of Group C decreased by 5.22% ($P > 0.05$). In conclusion, the combination of 2.0% yeast powder + 2.0% intestinal mucosa protein powder + 2.0% fish meal demonstrated the best efficacy in improving growth performance and economic benefits of nursery pigs, followed by

the combination of 1.5% plasma protein powder + 2.0% fish meal, whereas the combination of 3.0% intestinal mucosa protein powder + 5.0% fish meal was comparatively less effective.

Full Text

Effects of Different Protein Source Combinations on Growth Performance and Serum Biochemical Indices of Nursery Piglets

LI Yunhu[1], LIAO Peng[2], TANG Wei[3], FANG Rejun , DENG Zaofu[1], LI Wei[1], LI Meijun[1]*

[1]College of Animal Science and Technology, Hunan Biological and Electromechanical Polytechnic, Changsha 410127, China
[2]Institute of Subtropical Agriculture, Chinese Academy of Sciences, Changsha 410125, China
[3]Hunan Tianxin Wuling'er Animal Husbandry Co., Ltd., Zhuzhou 412307, China
College of Animal Science and Technology, Hunan Agricultural University, Changsha 410128, China

Abstract

This experiment investigated the effects of different protein source combinations on growth performance and serum biochemical indices of nursery piglets. Fish meal, spray-dried plasma protein (SDPP), yeast extract (YE), and dried porcine solubles (DPS) were added to diets at specific proportions. A total of 108 Duroc × Landrace × Yorkshire (DLY) nursery piglets with an initial body weight of (6.36 ± 0.20) kg were randomly allocated into three groups, each consisting of six replicates with six piglets per replicate. Group A (control) received a diet containing 1.5% SDPP + 2.0% fish meal, Group B received 3.0% DPS + 5.0% fish meal, and Group C received 2.0% YE + 2.0% DPS + 2.0% fish meal. The trial included a 3-day adaptation period followed by a 14-day experimental period. The results showed: (1) Average daily feed intake (ADFI) and average daily gain (ADG) in Group B were significantly lower than those in Groups A and C ($P < 0.05$). Compared with Group A, Group C exhibited increases of 1.76% in ADFI and 8.13% in ADG, though these differences were not significant ($P > 0.05$). Feed/gain ratio (F/G) in Groups B and C did not differ significantly from Group A ($P > 0.05$), but Group C had a significantly lower F/G than Group B ($P < 0.05$). (2) No significant differences were observed among the three groups in serum total protein, albumin, globulin, urea nitrogen, albumin/globulin ratio, or alanine transaminase and aspartate transaminase activities ($P > 0.05$). (3) Compared with Group A, money/gain ratio increased by 13.47% in Group B ($P > 0.05$) and decreased by 5.22% in Group C ($P > 0.05$). In conclusion, the combination of 2.0% YE + 2.0% DPS + 2.0% fish meal was most effective for improving growth performance and economic returns, followed

by the 1.5% SDPP + 2.0% fish meal combination, while the 3.0% DPS + 5.0% fish meal combination showed relatively poor efficacy.

Keywords: protein sources; combination; nursery piglets; growth performance; serum biochemical indices

Introduction

Nursery piglets have underdeveloped physiological functions, weak disease resistance, and poor environmental adaptability, making the selection of high-quality dietary protein sources critically important for their growth and health [1-2]. Animal-derived and single-cell protein sources are characterized by high protein content, rich and balanced amino acid profiles, and abundant micronutrients, vitamins, nutritional peptides (such as DPS and YE), immunoglobulins (such as SDPP), nucleotides (such as YE), unknown growth-promoting factors (such as fish meal), and other nutritional components. These sources contain no anti-nutritional factors and offer higher nutritional value compared to plant-based protein sources [3-4].

Recent advances in the application of animal-derived and single-cell protein sources in early-weaned piglet nutrition have led to the development of various products, including feed-grade fish meal processed from fish through oil removal, dehydration, and grinding; feed-grade SDPP produced from animal blood through plasma separation and spray drying; feed-grade DPS manufactured from porcine small intestine (to prevent cross-infection) through protease hydrolysis, special enzymatic treatment, high-temperature sterilization, and specialized drying; and feed-grade YE purified from specific yeast strains using advanced cell wall disruption and multi-enzyme hydrolysis technologies. These protein sources have demonstrated beneficial effects in practical production by improving protein utilization and immunity, reducing diarrhea rates, and alleviating weaning stress [5]. However, factors such as resource scarcity (e.g., fish meal), raw material sources, processing technologies, and biosafety concerns (e.g., DPS and SDPP) contribute to their high cost and price volatility, while their nutritional values each have distinct advantages and disadvantages.

To maximize their application value and effectiveness, researchers have investigated the substitution and combination of different protein sources. Studies indicate that protein sources exhibit substitutability, and specific combinations can produce synergistic effects that improve growth performance in weaned piglets compared to single sources [6-10]. Building upon our previous research examining the individual effects of 3% fish meal, 2% DPS, 3% YE, and 3% SDPP on nursery piglet growth performance [11], this study further explored different protein source combinations to investigate their effects on growth performance and serum biochemical indices. The objective was to provide reference data on combination effects and identify cost-effective formulations as viable alternatives to high-priced protein sources such as fish meal.

1.1 Experimental Materials

Spray-dried plasma protein was purchased from Weifang Purun Biotechnology Co., Ltd., with main nutritional components: crude protein 70%, crude ash 12%, moisture 10%, soluble chlorides 5%, and immunoglobulins 16%. Fish meal (Peruvian, standard steam-dried grade) was obtained with: crude protein 68%, crude ash 16%, crude fat 10%, moisture 10%, salt/sand 4%, and free fatty acids 7.58%. Yeast extract was sourced from Angel Yeast Co., Ltd., containing: mannan oligosaccharides 15%, -glucan 25%, crude protein 35-45%, crude fat 2-4%, crude fiber 0.5-0.8%, glutathione 0.3%, and moisture 8%. Dried porcine solubles were purchased from Beijing Zhongke Jingming Biotechnology Co., Ltd., with: crude protein 50%, methionine 1.1%, lysine 3.2%, threonine 2.0%, tryptophan 0.3%, and crude ash 18%.

1.2 Experimental Design

A single-factor experimental design was employed. A total of 108 healthy DLY nursery piglets at 28 days of age with an initial body weight of (6.36 ± 0.20) kg were randomly divided into three dietary treatment groups, each comprising six replicates of six piglets. Group A (control) received a diet containing 1.5% SDPP + 2.0% fish meal, while Groups B and C (treatment groups) received diets containing 3.0% DPS + 5.0% fish meal and 2.0% YE + 2.0% DPS + 2.0% fish meal, respectively.

1.3 Management

The feeding trial was conducted at Hunan Tianxin Wuling'er Animal Husbandry Co., Ltd. Facilities were disinfected one week before the experiment. Piglets were housed in enclosed pens, weighed before feeding, and feed was added according to consumption to maintain constant availability. Pens were cleaned twice daily, and immunization and deworming followed standard farm protocols. The trial consisted of a 3-day adaptation period and a 14-day experimental period.

1.4 Experimental Diets

Experimental diets were formulated according to NRC (2012) nutrient requirements for 5-10 kg piglets, with digestible energy at approximately 14.66 MJ/kg and crude protein at approximately 19%. Diet composition and nutrient levels are presented in Table 1 .

1.5.1 Growth Performance Indices

Average daily feed intake (ADFI) was calculated as the difference between daily feed offered and remaining feed per pen, divided by the number of experimental days. Average daily gain (ADG) was determined as average weight gain per piglet divided by experimental days. Feed/gain ratio (F/G) was calculated as ADFI divided by ADG.

1.5.2 Serum Biochemical Indices

At the end of the experiment, two healthy piglets from each replicate were selected for blood collection via anterior vena cava puncture. Serum was separated and stored at -20°C for subsequent analysis at the laboratory of Mawangdui Branch, Hunan Provincial People' s Hospital. Serum total protein (TP), albumin (ALB), globulin (GLB), urea nitrogen (UN), and activities of alanine transaminase (ALT) and aspartate transaminase (AST) were measured, and albumin/globulin ratio (ALB/GLB) was calculated.

1.5.3 Economic Benefit Analysis

Money/gain ratio (M/G) was calculated based on feed cost and F/G using the formula: M/G = feed cost × F/G.

1.6 Statistical Analysis

Experimental data were analyzed using one-way ANOVA in SPSS 21.0 software. Duncan' s multiple range test was used for post-hoc comparisons, with $P < 0.05$ considered statistically significant. Results are expressed as means ± standard deviation.

Results

2.1 Effects of Different Protein Source Combinations on Growth Performance of Nursery Piglets

As shown in Table 2 , ADFI in Group B was 16.09% lower than in Group A ($P < 0.05$), while Group C showed a 1.76% increase compared to Group A ($P > 0.05$). For ADG, Group B was 26.98% lower than Group A ($P < 0.05$), whereas Group C did not differ significantly from Group A ($P > 0.05$). No significant differences in F/G were observed between Groups B or C and Group A ($P > 0.05$). However, Group C had significantly higher ADFI and ADG and significantly lower F/G compared to Group B ($P < 0.05$).

2.2 Effects of Different Protein Source Combinations on Serum Biochemical Indices of Nursery Piglets

Table 3 shows that serum TP, ALB, GLB contents, ALB/GLB ratio, and ALT and AST activities did not differ significantly among the three groups ($P > 0.05$). Compared with Group A, serum UN content decreased by 19.25% in Group B and 15.72% in Group C, though these differences were not significant ($P > 0.05$). ALT and AST activities in Groups B and C were slightly lower than in the control group, but differences were not significant ($P > 0.05$). No significant differences in any serum biochemical indices were observed between Groups B and C ($P > 0.05$).

2.3 Economic Benefit Analysis

As presented in Table 4 , compared with Group A, money/gain ratio increased by 13.47% in Group B ($P > 0.05$) and decreased by 5.22% in Group C ($P > 0.05$). Additionally, Group C showed a 16.47% lower money/gain ratio than Group B ($P > 0.05$).

Discussion

3.1 Effects of Different Protein Source Combinations on Growth Performance

Animal-derived and single-cell protein sources possess unique nutritional characteristics beyond high protein content and balanced amino acid profiles. Fish meal is considered a premium animal protein source containing unknown growth-promoting factors and -3 fatty acids, though its application is limited by declining fishery resources, high price volatility, and quality issues related to its high fat, calcium, phosphorus, and salt content. Spray-dried plasma protein is rich in immunoglobulins, growth factors, interferons, hormones, and lysozyme, but its use is constrained by biosafety and processing considerations. Dried porcine solubles contain abundant small peptides and free amino acids that are easily digested and can enhance immunity, though similarly affected by biosafety and processing factors. Yeast extract is rich in nucleotides, nutritional peptides, glutathione, and yeast cell wall polysaccharides, offering good palatability and immunomodulatory effects, but is influenced by processing technology and cost.

Previous studies have demonstrated the efficacy of these protein sources individually. Research by Dai et al. [12] and Murray et al. [13] showed that fish meal is highly effective for early-weaned piglets, providing essential -3 fatty acids that improve health and reduce severity of colibacillosis. Hansen et al. [14] and Pierce et al. [15] reported that SDPP significantly improves growth performance in early-weaned piglets, primarily due to its immunoglobulin content. Boza et al. [16] and Wang et al. [17] confirmed that DPS enhances protein utilization and promotes intestinal development while reducing diarrhea rates. Mathew et al. [18], Ren et al. [19], and Pan et al. [20] demonstrated that yeast extracts act as potent flavor enhancers with excellent palatability, immunomodulatory, and growth-promoting properties.

Combinations of these protein sources can produce synergistic effects superior to single sources. Wang et al. [21] found that replacing 25% or 50% of imported fish meal with active yeast protein powder resulted in higher ADG and lower F/G compared to complete replacement or fish meal alone. Zeng [22] reported that replacing 4.5% fish meal with 5.83% DPS + 3.6% SDPP significantly improved ADG without affecting ADFI or F/G. Kats et al. [23] observed that piglets fed diets containing 7.5% SDPP + 1.63% spray-dried blood meal showed superior growth performance compared to single-source diets during days 0-14 post-weaning.

Our results indicate that the combination of 2.0% YE + 2.0% DPS + 2.0% fish meal (Group C) was most effective for improving ADFI, ADG, and F/G, followed by the 1.5% SDPP + 2.0% fish meal combination (Group A), while the 3.0% DPS + 5.0% fish meal combination (Group B) showed the poorest efficacy. The superior performance of Group C may be attributed to the combined presence of high-quality protein, balanced amino acids, small peptides, free amino acids, nucleotides, and unknown growth factors, particularly the strong flavor-enhancing properties of yeast extract that improve palatability and biological value. Further research is needed to determine optimal combination ratios and elucidate the underlying mechanisms of these synergistic effects.

3.2 Effects of Different Protein Source Combinations on Serum Biochemical Indices

Serum total protein comprises albumin and globulin, correlating positively with tissue protein synthesis. Higher serum TP content indicates greater capacity for protein synthesis and organ growth. Albumin, synthesized by the liver, maintains plasma colloid osmotic pressure, transports nutrients, and generates body proteins, serving as a sensitive indicator of protein malnutrition. Globulin, produced by plasma cells derived from B cells, has immunological functions and reflects antibody levels and immune status. The albumin/globulin ratio is an important immune status indicator, with decreased values suggesting enhanced immune function.

Urea nitrogen is the end product of protein and amino acid metabolism, showing significant negative correlation with nitrogen retention and protein/amino acid utilization. As the primary organ for UN excretion, kidney function can be evaluated through serum UN content, which accurately reflects protein metabolism and amino acid balance. ALT and AST are primarily distributed in liver cells and other tissues, participating in transamination reactions and reflecting protein synthesis and amino acid metabolism. Under normal conditions, their blood activities are low, but increase markedly when tissue damage occurs or cell permeability increases, making them important clinical indicators for liver function.

Shi et al. [24] investigated various protein source combinations replacing 4% SDPP and found no significant effects on serum TP, ALB, GLB, or ALB/GLB, suggesting no substantial impact on immune function. While casein replacement slightly increased serum UN, other combinations decreased UN, indicating comparable or superior protein/amino acid composition to SDPP. No significant effects on ALT and AST activities were observed, suggesting minimal impact on amino acid metabolism and protein synthesis. Our findings align with these results, as no significant differences in serum TP, ALB, GLB, UN, ALB/GLB, ALT, or AST were detected among Groups A, B, and C, indicating that the three protein source combinations did not differentially affect immunity, protein/amino acid composition, synthesis, or liver development.

3.3 Economic Benefit Analysis

Money/gain ratio is an economic indicator reflecting feed cost efficiency in livestock production, whereas feed/gain ratio only indicates feed quality and animal performance without accounting for cost-effectiveness. Although lower F/G typically corresponds to lower M/G, both parameters must be considered for comprehensive evaluation of feed economics.

Based on prevailing feed prices during the experiment, the 3.0% DPS + 5.0% fish meal combination showed a 13.47% higher money/gain ratio compared to the control (1.5% SDPP + 2.0% fish meal), while the 2.0% YE + 2.0% DPS + 2.0% fish meal combination reduced money/gain ratio by 5.22% ($P > 0.05$). The YE + DPS + fish meal combination thus demonstrated the lowest money/gain ratio and best economic returns.

Conclusion

Based on the comprehensive results of this study, the combination of 2.0% yeast extract + 2.0% dried porcine solubles + 2.0% fish meal was most effective for improving growth performance and economic benefits in nursery piglets, followed by the 1.5% spray-dried plasma protein + 2.0% fish meal combination, while the 3.0% dried porcine solubles + 5.0% fish meal combination showed relatively poor efficacy.

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