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

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Abstract

This experiment combined fish meal, plasma protein powder, yeast powder, and intestinal mucosa protein powder at certain proportions and added them to the diet, aiming to compare the effects of different protein source combinations on growth performance and serum biochemical indices of nursery pigs. A total of 108 three-way crossbred nursery pigs (Duroc × Landrace × Yorkshire) 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, 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 pre-trial period and a 14-day formal trial period. The results showed that: 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, there were no significant differences 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 observed among the three groups in serum total protein, albumin, globulin, urea nitrogen content, albumin/globulin ratio, or alanine aminotransferase and aspartate aminotransferase activities ($P>0.05$). 3) Compared with Group A, the cost-weight ratio of Group B increased by 13.47% ($P>0.05$), while that of Group C decreased by 5.22% ($P>0.05$). These results indicate that the combination of 2.0% yeast powder + 2.0% intestinal mucosa protein powder + 2.0% fish meal achieved the best effects 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 relatively less effective.

Full Text

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

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Abstract

This experiment investigated the effects of different protein source combinations on growth performance and serum biochemical indices of nursery piglets by adding fish meal, spray-dried plasma protein (SDPP), yeast extract (YE), and dried porcine solubles (DPS) to diets at specific proportions. A total of 108 "Duroc × Landrace × Yorkshire" crossbred 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) Group B exhibited significantly lower average daily feed intake (ADFI) and average daily gain (ADG) compared to Groups A and C ($P < 0.05$). Compared with Group A, Group C showed increases of 1.76% in ADFI and 8.13% in ADG, though these differences were not significant ($P > 0.05$). Feed-to-gain ratio (F/G) did not differ significantly between Groups B and C versus the control ($P > 0.05$), 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 content, albumin-to-globulin ratio, or alanine transaminase and aspartate transaminase activities ($P > 0.05$). (3) Compared with Group A, the cost-to-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 demonstrated the best effects on improving growth performance and economic benefits, 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, poor disease resistance, and low environmental adaptability, making the selection of high-quality dietary protein sources critically important for their growth and health. Animal-derived and single-cell protein sources offer high protein content with abundant and well-balanced amino acid profiles, and are rich in 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 various other nutrients. These sources contain no anti-nutritional factors and possess higher nutritional value compared to plant-based proteins.

Recent advances in the application of animal-derived and single-cell protein sources in early-weaned piglet nutrition have yielded promising results. Currently available products include feed-grade fish meal processed from fish through oil removal, dehydration, and grinding; spray-dried plasma protein powder derived from animal blood; dried porcine solubles produced from porcine small intestines through protease hydrolysis, special enzymatic treatment, high-temperature sterilization, and specialized drying; and feed yeast powder refined from specific yeast strains using high-efficiency cell wall disruption and multi-enzyme hydrolysis technology. These protein sources have demonstrated beneficial effects in practical production by improving protein utilization and immunity, reducing diarrhea rates, and alleviating weaning stress. However, factors such as resource scarcity (e.g., fish meal), raw material sources, processing technology, and biosafety concerns (e.g., DPS and SDPP) contribute to their high cost and price volatility, while each source has distinct nutritional advantages and limitations.

To maximize their application value and effectiveness, researchers have investigated the substitution and combination of different protein sources. Studies indicate that protein sources exhibit mutual substitutability, and specific combinations demonstrate synergistic effects that can improve growth performance in weaned piglets more effectively than single sources. Building upon our previous research examining the individual effects of different animal-derived and single-cell protein sources (3% fish meal, 2% DPS, 3% YE, and 3% SDPP) on nursery piglet growth performance, this study further explored various protein source combinations to evaluate their combined effects on growth performance and serum biochemical indices. The objective was to provide reference data for

understanding combination effects and to identify cost-effective formulations as viable alternatives to high-priced protein sources like fish meal.

Materials and Methods

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, sourced from Peru, was standard steam-dried grade containing: crude protein 68%, crude ash 16%, crude fat 10%, moisture 10%, salt/sand 4%, and free fatty acids 7.58%. Yeast extract was obtained from Angel Yeast Co., Ltd., with: 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., containing: 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 "Duroc × Landrace × Yorkshire" crossbred 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 Animal Management The feeding trial was conducted at Hunan Tianxin Wuling' er Animal Husbandry Co., Ltd. All pens were disinfected one week before the experiment. Piglets were housed in enclosed pens, with feed added according to consumption to maintain continuous availability. Pens were cleaned twice daily, and immunization and deworming followed the farm' s standard procedures. 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 .

Table 1 Composition and nutrient levels of experimental diets (air-dry basis)

Note: The premix provided per kilogram of diet: VA 5,600 IU, VD 500 IU, VE 66 IU, VB 28 g, VB 5 mg, D-pantothenic acid 12.5 mg, nicotinic acid 30 mg, Mn 100 mg, Zn 100 mg, Fe 100 mg, Cu 150 mg, I 0.20 mg, Se 0.25 mg.

Crude protein, calcium, and total phosphorus were measured values; others were calculated values.

1.5 Measurement Indices 1.5.1 Growth Performance

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

1.5.2 Serum Biochemical Indices

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

1.5.3 Economic Benefit Analysis

Cost-to-gain ratio (money/gain, 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 mean ± standard deviation.

Results

2.1 Effects on Growth Performance As shown in Table 2 , Group B exhibited a 16.09% reduction in ADFI compared with Group A ($P < 0.05$), while Group C showed a 1.76% increase ($P > 0.05$). 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 the control ($P > 0.05$). However, Group C demonstrated significantly higher ADFI and ADG and significantly lower F/G compared with Group B ($P < 0.05$).

Table 2 Effects of different protein source combinations on growth performance of nursery piglets

Note: In the same row, values with different superscripts differ significantly (P < 0.05). The same applies below.

2.2 Effects on Serum Biochemical Indices Table 3 shows that Groups B and C did not differ significantly from Group A in serum TP, ALB, GLB contents, or ALB/GLB ratio ($P > 0.05$). Compared with Group A, serum UN content decreased by 19.25% in Group B and 15.72% in Group C, but 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, with no significant differences ($P > 0.05$). Furthermore, no significant differences were detected between Groups B and C for any serum biochemical parameter ($P > 0.05$).

Table 3 Effects of different protein source combinations on serum biochemical indices of nursery piglets

2.3 Economic Benefit Analysis As presented in Table 4 , compared with Group A, the cost-to-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 cost-to-gain ratio than Group B ($P > 0.05$).

Table 4 Economic benefit analysis

Discussion

3.1 Effects on Growth Performance Animal-derived and single-cell protein sources exhibit 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 constrained 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 affected by biosafety and processing concerns. Dried porcine solubles contain abundant small peptides and free amino acids that are easily digested and can enhance immunity, though similarly impacted by biosafety and processing factors. Yeast extract is rich in nucleotides, nutritional peptides, glutathione, and yeast cell wall polysaccharides, offering excellent palatability and immunomodulatory effects, but is influenced by processing technology and cost.

Previous studies have demonstrated the efficacy of these protein sources individually. Fish meal supplementation provides essential -3 fatty acids that improve piglet health and reduce susceptibility to Escherichia coli infections. Spray-dried plasma protein significantly enhances growth performance in early-weaned piglets, primarily attributed to its immunoglobulin content and bioactive compounds. Dried porcine solubles improve protein utilization through readily absorbable peptides and free amino acids, while enhancing immune organ indices and immunoglobulin levels, promoting intestinal development and reducing diarrhea. Yeast extracts serve as potent flavor enhancers that increase

feed palatability and exhibit strong immunostimulatory and growth-promoting properties.

Combinations of these protein sources can produce synergistic effects superior to single-source supplementation. Research has shown that replacing 25% or 50% of imported fish meal with active yeast protein powder maintained comparable growth performance while improving feed efficiency. Other studies found that combinations of 5.83% DPS and 3.6% SDPP replacing 4.5% fish meal significantly increased ADG without affecting ADFI or F/G. Furthermore, diets containing 7.5% SDPP plus 1.63% spray-dried blood meal improved growth performance more effectively than any single protein source during the first 14 days post-weaning.

Limited research exists on specific combinations of animal-derived and single-cell protein sources for nursery piglets. One study comparing combinations of 3% SDPP + 2% DPS, 5% whole milk powder + 4% HP 300, and 3% HP 300 + 15% high-protein whey powder found no significant differences in post-weaning intake, ADG, or F/G, though the HP 300 and whey powder combination yielded the highest ADG. Another investigation evaluating combinations of wheat hydrolyzed protein + imported yeast extract, soy protein isolate + imported yeast extract, and soy protein isolate + domestic yeast extract revealed significant differences in ADFI among treatments but not in F/G, with significant ADG differences between some combinations.

Building on our previous work examining individual protein sources, this study adjusted proportions to explore combination effects. The superior performance of Group C, with significantly higher ADFI and ADG and lower F/G compared with Group B, may be attributed to the combined presence of high-quality protein, balanced amino acids, small peptides, free amino acids, nucleotides, and unknown growth factors. The strong palatability-enhancing effect of yeast extract likely contributed to the improved biological value. However, the optimal proportion ranges and underlying mechanisms for these synergistic effects require further investigation.

3.2 Effects on Serum Biochemical Indices Serum total protein comprises albumin and globulin, correlating positively with tissue protein synthesis capacity. Higher serum TP indicates greater potential 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 lymphocytes, provides immune function and reflects antibody levels and immune status. The albumin-to-globulin ratio is an important immune status marker; a decreased ratio indicates enhanced immune function.

Urea nitrogen represents the end product of protein and amino acid metabolism, correlating negatively with nitrogen retention and protein/amino acid utilization. As the primary organ for UN excretion, kidney function significantly influ-

ences serum UN levels, making it a valuable indicator of protein metabolism and amino acid balance. Alanine transaminase and aspartate transaminase are predominantly located in liver cells and other tissues, participating in amino group transfer reactions. Under normal conditions, their serum activities are low, but increase substantially when tissue damage or increased membrane permeability occurs, making them important clinical markers for liver function.

Previous research evaluating various protein source combinations as replacements for SDPP found no significant effects on serum TP, ALB, GLB, or ALB/GLB, suggesting no substantial impact on immune function. While casein replacement slightly increased UN levels, 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 were detected among Groups A, B, and C in serum TP, ALB, GLB, UN, ALB/GLB, ALT, or AST, indicating that the three protein source combinations produced similar effects on immune function, protein/amino acid composition and synthesis, and liver development.

3.3 Economic Benefit Analysis The cost-to-gain ratio is an economic indicator reflecting feed cost efficiency in livestock production, whereas feed-to-gain ratio only reflects feed quality and animal performance without accounting for economic viability. Although lower F/G typically corresponds to lower cost-to-gain ratio, both parameters must be considered for comprehensive feed efficiency evaluation.

Based on prevailing feed prices during this experiment, the cost-to-gain ratio differences between the control (1.5% SDPP + 2.0% fish meal) and the treatment groups were not statistically significant ($P > 0.05$). However, the 3.0% DPS + 5.0% fish meal combination increased costs by 13.47%, while the 2.0% YE + 2.0% DPS + 2.0% fish meal combination reduced costs by 5.22%. These results demonstrate that the yeast-containing combination offered the lowest cost-to-gain ratio and thus the 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 proved most effective for improving growth performance and economic benefits in nursery piglets. The 1.5% spray-dried plasma protein + 2.0% fish meal combination ranked second, while the 3.0% dried porcine solubles + 5.0% fish meal combination showed relatively inferior performance.

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