Effects of Compound Microecological Preparation on Growth Performance, Serum Biochemical Parameters, Immune Indices, and Fecal Volatile Fatty Acid Content in Weaned Piglets (Postprint)

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Abstract

This experiment was conducted to investigate the effects of compound microecological preparation on growth performance, serum biochemical and immune indices, and fecal volatile fatty acid content in weaned piglets. A total of 240 weaned piglets (10.0±0.3 kg), half male and half female, were randomly divided into 4 groups with 6 replicates per group and 10 piglets per replicate. Group I (control group) was fed the basal diet containing 1% kitasamycin and 2% colistin, while Groups II, III and IV were supplemented with 50, 100 and 150 mL of compound microecological preparation per piglet per day, respectively, in addition to the basal diet. The trial consisted of a 5-day pre-test period and a 28-day formal test period. On days 1 and 28 of the trial, blood samples were collected from the anterior vena cava of piglets to determine serum biochemical and immune indices, and rectal contents were collected to determine fecal volatile fatty acid content. The results showed that: 1) Compared with the control group, Group II exhibited a significant increase in average daily gain (23.53%, $P<0.05$) and a significant decrease in feed-to-gain ratio (15.86%, $P<0.05$), while the diarrhea rate was reduced by 47.16% ($P>0.05$). 2) On day 1, no significant differences were observed in serum biochemical and immune indices among groups ($P>0.05$), while fecal volatile fatty acid content was higher in the treatment groups than in the control group. 3) On day 28, Group II showed higher activities of alkaline phosphatase and aspartate aminotransferase in serum ($P>0.05$), as well as higher contents of glucose, total protein, albumin and globulin ($P>0.05$), whereas serum urea nitrogen content was decreased by 18.27% ($P>0.05$) compared with the control group. Compared with the control group, fecal acetate, propionate and butyrate contents in Group II were

increased by 21.03% (P>0.05), 41.08% (P>0.05) and 77.84% (P<0.05), respectively. It can be concluded that dietary supplementation of 50 mL of compound microecological preparation per pig per day can improve growth performance, reduce diarrhea rate, enhance immune function and increase fecal volatile fatty acid content in weaned piglets.

Full Text

Effects of Compound Probiotics on Growth Performance, Serum Biochemical and Immune Indices, and Volatile Fatty Acid Contents in Feces of Weaned Piglets

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Abstract

This experiment was conducted to investigate the effects of compound probiotics on growth performance, serum biochemical and immune indices, and volatile fatty acid contents in feces of weaned piglets. Two hundred and forty weaned piglets (half male and half female) with an average body weight of (10.0±0.3) kg were randomly allocated into 4 groups with 6 replicates per group and 10 pigs per replicate. Piglets in group I (control group) were fed a basal diet (containing 1% kitasamycin and 2% colistin), while those in groups II, III, and IV were fed the basal diet supplemented with 50, 100, and 150 mL of compound probiotics per day per piglet, respectively. The experiment consisted of a 5-day pre-trial period followed by a 28-day formal trial period. On days 1 and 28 of the experiment, blood samples were collected from the precaval vein to determine serum biochemical and immune indices, and rectal contents were collected to measure volatile fatty acid contents in feces.

The results showed: 1) Compared with the control group, the average daily gain of piglets in group II was significantly increased by 23.53% (P<0.05), the feed-to-gain ratio was significantly decreased by 15.86% (P<0.05), and the diarrhea rate was reduced by 47.16% (P>0.05). 2) On day 1 of the experiment, there were no significant differences in serum biochemical and immune indices among groups (P>0.05), while the volatile fatty acid contents in feces of piglets in the experimental groups were higher than those in the control group. 3) On day 28 of the experiment, the activities of alkaline phosphatase and aspartate aminotransferase and the contents of glucose, total protein, albumin, and globulin in serum of piglets in group II were higher than those in the control group (P>0.05), while the serum urea nitrogen content was reduced by 18.27% compared with the control group (P>0.05). Compared with the control group, the contents of acetic acid, propionic acid, and butyric acid in feces of group

II were increased by 21.03% (P>0.05), 41.08% (P>0.05), and 77.84% (P<0.05), respectively. These results indicate that dietary supplementation with 50 mL of compound probiotics per day per piglet can improve growth performance, reduce diarrhea rate, enhance immune function, and increase volatile fatty acid contents in feces of weaned piglets.

Keywords: compound probiotics; weaned piglets; growth performance; serum biochemical index; volatile fatty acid

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Introduction

Intensive modern farming practices can easily disrupt the intestinal microbial flora balance in animals, leading to digestive disorders, hindered growth, and increased production costs [1]. Antibiotics can influence the initial colonization of intestinal microorganisms in the host, thereby promoting growth [2]. While antibiotic feed additives can improve economic efficiency, their extensive use is associated with numerous negative effects, including antibiotic residues in animal products that pose potential health risks to humans and may increase microbial resistance to antibiotics. Research has demonstrated that probiotics can replace antibiotics in piglet production, improving feed intake, growth performance, and immune function while promoting beneficial bacteria and inhibiting harmful bacteria in the intestine [3-5]. Therefore, this study investigated the effects of different supplementation levels of compound probiotics on growth performance, serum biochemical and immune indices, and volatile fatty acid contents in feces of weaned piglets, aiming to provide a foundation for developing safe, efficient, and environmentally friendly compound probiotics for widespread application in animal production.

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Materials and Methods

1.1 Experimental Materials

The compound probiotics used in this study were provided by Guangzhou Bai' aofei Biotechnology Co., Ltd. The product was a light yellow powder containing a mixture of lactic acid bacteria and yeast, along with their culture medium. For preparation, water in the fermentation tank was heated to 24°C, the compound probiotics powder was added, and the mixture was fermented anaerobically at constant temperature for 18 hours. The fermented compound probiotics had a pH of 3.59, with viable counts of 1×10 CFU/mL for lactic acid bacteria and 8×10 CFU/mL for yeast. Each batch of fermented compound probiotics was used within 2 days, and anaerobic conditions were maintained throughout fermentation and use. The experimental diets were formulated according to NRC (2012) standards, and the composition and nutrient levels of the basal diet are shown in Table 1 .

1.2 Experimental Design

Two hundred and forty weaned piglets (Duroc × Landrace) with an average body weight of (10.0±0.3) kg (half male and half female) were randomly divided into 4 groups with 6 replicates per group and 10 piglets per replicate. Piglets in group I were fed the basal diet (containing 1% kitasamycin and 2% colistin), while those in groups II, III, and IV were fed the basal diet supplemented with 50, 100, and 150 mL of compound probiotics fermentation liquid per piglet per day, respectively. The experiment was conducted at Luyi Tianzhong Breeding Base in Henan Province, with a 5-day pre-trial period followed by a 28-day formal trial period.

1.3 Feeding Management

The on-farm trial was conducted strictly according to conventional pig farm management protocols, including required vaccination and deworming procedures. All groups were fed mixed feed at 07:00, 10:00, 13:30, and 15:30 daily.

1.4.1 Growth Performance

On days 1 and 28 of the formal trial period, weaned piglets were weighed after fasting to calculate average daily gain. Daily feed intake was recorded for each group, and total feed consumption was calculated at the end of the trial to determine average daily feed intake and feed-to-gain ratio. Fecal conditions were observed daily at 08:00, and the number of piglets with diarrhea was recorded to calculate diarrhea rate using the following formula:

Diarrhea rate (%) = 100 × (number of piglets with diarrhea) / (total number of piglets × trial days)

1.4.2 Serum Biochemical and Immune Indices

On days 1 and 28 of the formal trial period, 6 weaned piglets with similar body weight were randomly selected from each group at 08:00, and 5 mL blood samples were collected from the precaval vein into procoagulant vacuum tubes. After standing on a slant for 0.5 hours, serum was separated by centrifugation at 3,000 r/min for 15 minutes. The supernatant was collected and stored at -20°C. Serum samples were sent to Heilongjiang Provincial People' s Hospital, where alkaline phosphatase (ALP) and aspartate aminotransferase (AST) activities, as well as glucose (GLU), urea nitrogen (UN), total protein (TP), albumin (ALB), and globulin (GLB) contents were measured using a Hitachi 7020 automatic biochemical analyzer.

1.4.3 Determination of Volatile Fatty Acid Content in Feces

On days 1 and 28 of the formal trial period at 15:00, rectal contents were aseptically and anaerobically collected from 3 randomly selected piglets per group and placed in 50 mL sterile screw-cap tubes, which were immediately stored at -20°C. Approximately 2 g of feces was transferred to a centrifuge tube, mixed with 2 volumes of ultrapure water, and centrifuged at 10,000 r/min for 15 minutes at 4°C. The supernatant was divided into 2 EP tubes as volatile fatty acid samples. For analysis, 1.5 mL of fecal supernatant was mixed with 0.2 mL of 8.2% metaphosphoric acid, incubated in a water bath for 30 minutes, and centrifuged at 10,000 r/min for 10 minutes at 4°C. The resulting supernatant was used to determine acetic acid, propionic acid, and butyric acid contents by GC-2010 gas chromatography.

1.5 Statistical Analysis

Data were analyzed using one-way ANOVA with SPSS 22.0 statistical software, and multiple comparisons were performed using LSD. Differences were considered significant at $P<0.05$. Data are expressed as means ± standard error.

Results

2.1 Effects of Compound Probiotics on Growth Performance of Weaned Piglets

As shown in Table 2 , group II had the highest average daily gain, while group I had the lowest. The average daily gain of groups II, III, and IV was significantly higher than that of group I ($P<0.05$), with increases of 23.53%, 20.59%, and 14.71%, respectively ($P<0.05$). No significant differences in average daily feed intake were observed among the four groups ($P>0.05$). Significant differences in feed-to-gain ratio were detected among groups ($P<0.05$), with group I showing a significantly higher ratio than the other groups ($P<0.05$). Compared with group I, the feed-to-gain ratio of group II was reduced by 15.86% ($P<0.05$). No significant differences in diarrhea rate were found among the four groups ($P>0.05$); however, group II exhibited the lowest diarrhea rate, which was 47.16% lower than that of group I ($P>0.05$).

2.2 Effects of Compound Probiotics on Serum Biochemical and Immune Indices of Weaned Piglets

As shown in Table 3 , on day 1 of the experiment, no significant differences were observed among groups in alkaline phosphatase and aspartate aminotransferase activities, urea nitrogen and glucose contents, or total protein, albumin, globulin, and albumin/globulin ratio (P>0.05). On day 28, no significant differences were detected among groups in alkaline phosphatase activity (P>0.05), though group III showed the highest activity. Similarly, no significant differences were found in aspartate aminotransferase activity among groups (P>0.05). No significant differences were observed in serum urea nitrogen and glucose contents among groups (P>0.05), though urea nitrogen content in group II was 18.27% lower than that in group I (P>0.05). No significant differences were detected among groups in serum total protein, albumin, globulin, or albumin/globulin ratio (P>0.05).

2.3 Effects of Compound Probiotics on Volatile Fatty Acid Contents in Feces of Weaned Piglets

As shown in Table 4 and Table 5 , on day 1 of the experiment, significant differences were observed among groups in acetic acid content (P<0.05), with groups II, III, and IV showing increases of 63.41%, 61.76%, and 76.63% compared with group I (P<0.05), respectively. Significant differences were also found in propionic acid content among groups (P<0.05), with groups II, III, and IV showing increases of 88.86%, 28.20%, and 35.21% compared with group I (P<0.05), respectively. No significant differences were detected in butyric acid content among the four groups (P>0.05), though groups II, III, and IV showed increased levels compared with group I.

On day 28 of the experiment, significant differences were observed among groups in acetic acid content (P<0.05). Compared with group I, groups II, III, and IV showed increases of 21.03% (P>0.05), 3.19% (P>0.05), and 40.69% (P<0.05), respectively. Significant differences were also found in propionic acid content among groups (P<0.05), with group IV showing a 107.11% increase compared with group I (P<0.05), while groups II and III showed increases that were not statistically significant (P>0.05). Significant differences were detected in butyric acid content among groups (P<0.05), with groups II, III, and IV showing increases of 77.84% (P<0.05), 30.15% (P>0.05), and 76.03% (P<0.05) compared with group I, respectively.

Discussion

3.1 Effects of Compound Probiotics on Growth Performance of Weaned Piglets

Direct feeding of fermented probiotics mixed with diets is rarely reported in the literature. Most existing studies have focused on fermenting feed ingredients or directly adding beneficial bacteria to diets. Yue et al. [6] reported that compound probiotics fermented soybean meal could promote intestinal development, improve digestive enzyme activity, reduce diarrhea rate, and enhance growth performance in piglets. Abe et al. [7] found that newborn piglets orally administered with *Bifidobacterium* and lactic acid bacteria preparations showed significantly higher average daily gain than the control group. Estienne et al. [8] demonstrated that microbial agents could improve average daily gain in pigs. Liu et al. [9] reported that compound probiotics fermented diets significantly improved the apparent digestibility of various nutrients and enhanced growth performance in finishing pigs. Wu et al. [10] found that feeding compound probiotics fermented diets to finishing pigs reduced feed-to-gain ratio by 9.76% and increased weight gain by 18.03% compared with non-fermented complete powder feed, while effectively reducing diarrhea rate in piglets. Liu et al. [11] showed that probiotics preparations significantly increased average daily gain and decreased feed-to-gain ratio in weaned piglets. The present study, which used compound probiotics mixed directly with diets, yielded results consistent with previous research. Notably, based on comprehensive evaluation of average daily gain, average daily feed intake, feed-to-gain ratio, and diarrhea rate, supplementation with 50 mL of compound probiotics fermentation liquid per piglet per day produced the optimal effect, significantly improving average daily gain, reducing feed-to-gain ratio, and decreasing diarrhea rate. These findings suggest that higher doses of compound probiotics do not necessarily result in better growth performance, indicating that there is an optimal supplementation level and range for compound probiotics.

3.2 Effects of Compound Probiotics on Serum Biochemical and Immune Indices of Weaned Piglets

Serum biochemical indices provide a comprehensive reflection of metabolic function, with changes in blood biochemical parameters indicating alterations in metabolic activity. Within a certain range, higher glucose content in the body represents stronger capacity for glucose utilization in anabolic metabolism. As an energy substrate for metabolism, glucose is an important monosaccharide that serves as the most effective nutrient for rapid energy supply to support vital activities and provides energy for protein synthesis in the body. Additionally, glucose absorption promotes insulin release, which facilitates protein synthesis [12]. Serum alanine aminotransferase and aspartate aminotransferase are important markers of liver and heart function; elevated activities may indicate liver or heart damage [13]. Tang et al. [14] reported that serum alkaline phosphatase activity could reflect the efficiency of protein and lipid metabolism, as well as growth rate and performance. The present results showed no significant differences in serum alkaline phosphatase activity among groups on day 1, but higher activity in group II than in group I on day 28, further confirming that compound probiotics can improve growth performance in weaned piglets. In this study, group II exhibited the highest average daily gain and the lowest feed-to-gain ratio and diarrhea rate. The possible reason is that increasing doses of compound probiotics may cause diarrhea in weaned piglets, leading to reduced feed intake and weight gain. Meanwhile, under similar feed intake conditions, the 100 mL dose provided increased microbial numbers compared with the 50 mL dose, which may explain the higher alkaline phosphatase activity observed in group III. Serum biochemical indices reflect the metabolic status of weaned piglets. Serum total protein and urea nitrogen contents can accurately reflect protein metabolism absorption and the balance of volatile fatty acids in the diet [15-16]. Lower serum urea nitrogen content indicates greater urea nitrogen deposition and more efficient conversion of urea nitrogen into body protein, thereby promoting animal growth. Gao et al. [17] reported that adding 6% probiotics fermented apple pomace could reduce serum urea nitrogen content in weaned piglets. The present study showed no significant differences in serum urea nitrogen content among groups on day 1, but lower urea nitrogen content in group III than in the control group on day 28, suggesting that compound probiotics can increase urea nitrogen deposition, facilitate protein synthesis, and promote piglet growth.

Serum total protein content reflects protein absorption status and its relationship with humoral immunity. Compound probiotics contain abundant lactic acid bacteria and yeast, whose cellular components can effectively stimulate the intestine and act as immune adjuvants to promote the growth and development of immune organs. Serum total protein consists of albumin and globulin, representing the most abundant solid components in serum, and functions to maintain normal colloid osmotic pressure and pH in blood vessels and transport various metabolites [18]. Serum globulin is produced by macrophages in the body; increased circulating antibody levels lead to elevated serum globulin content. Globulin can mount immune responses against foreign specific antigens to protect the body from foreign substances, and its content can reflect immune status and physiological condition to a certain extent. Increased globulin content can elevate serum total protein content [19]. Wang et al. [20] reported that dietary supplementation with lactic acid bacteria could improve non-specific immune function in juvenile *Litopenaeus vannamei*. Dong et al. [21] demonstrated that dietary supplementation with a compound preparation of *Bacillus licheniformis*, *Bacillus subtilis*, and *Lactobacillus plantarum* could enhance immune performance. The present results are consistent with previous studies. Compound probiotics contain abundant microorganisms that can influence intestinal colonization and composition, exerting certain stimulatory effects on host digestion and immune function [22].

3.3 Effects of Compound Probiotics on Volatile Fatty Acid Contents in Feces of Weaned Piglets

The digestive tract of piglets contains numerous microorganisms that coexist interdependently and constrain each other, forming a dynamic microecological balance system. When piglets experience stress, this intestinal microecological balance is disrupted, leading to flora imbalance and poor growth performance. The digestive tract (ileum, cecum, and colon) of weaned piglets contains abundant microorganisms capable of fermenting carbohydrates to produce various volatile fatty acids (such as acetic acid, propionic acid, and butyric acid). These small molecular volatile fatty acids protect intestinal health by serving as energy substrates, inhibiting harmful bacteria growth, and promoting intestinal epithelial cell proliferation and mucosal growth. The volatile fatty acid content and intestinal health status of weaned piglets can be indirectly reflected through rectal contents (feces). In this study, the experimental groups showed higher volatile fatty acid contents in feces than the control group, consistent with previous research. Zhang et al. [23] reported that dietary supplementation with swine-derived *Lactobacillus salivarius* could improve intestinal microecological balance. Hou [24] and Mallo et al. [25] demonstrated that dietary supplementation with lactic acid bacteria in weaned piglets could significantly increase *Lactobacillus* counts and decrease *Escherichia coli* counts in the ileum, cecum, and feces. Giang et al. [26] noted that the primary mechanism by which lactic acid bacteria inhibit pathogen growth is through organic acid production, which increases organic acid content and reduces intestinal pH, thereby inhibiting harmful bacteria. Gao et al. [12] reported that adding 6% probiotics apple fermentation liquid could improve intestinal flora balance in piglets. Based on the comprehensive results of this study, supplementation with 50 mL of compound probiotics per piglet per day is most appropriate, as this level can improve intestinal flora status, nutritional status, and intestinal health in weaned piglets.

In conclusion, compound probiotics can improve growth performance and immune function, enhance intestinal function, reduce diarrhea rate, and increase volatile fatty acid contents in feces of weaned piglets, with the optimal effect observed at a supplementation level of 50 mL per piglet per day.

References

[1] NOUSIAINEN J, SETÄLÄ J. Lactic acid bacteria as animal probiotics[C]//SALMINEM S, VON WRIGHT A. Lactic acid bacteria: microbiology and functional aspects. New York: Marcel Dekker Inc, 1998: 437–473.

[2] 萨仁娜, 张琪, 谷春涛, 等. 微生物饲料添加剂对肉仔鸡大肠杆菌抑制及血液生化指标的影响 [J]. 饲料研究, 2006(3): 4–8.

[3] 王士长, 陈静, 潘健存, 等. 植物乳杆菌对断奶仔猪生产性能和血液生化指标的影响 [J]. 中国畜牧兽医, 2006, 33(8): 67–70.

[4] 张董燕, 季海峰, 王晶, 等. 猪源罗伊氏乳酸杆菌对断奶仔猪生长性能和血清指标的影响 [J]. 动物营养学报, 2011, 23(9): 1553-1559.

[5] WEN K, LI G H, BUI T, et al. High dose and low dose *Lactobacillus acidophilus* exerted differential immune modulating effects on T cell immune responses induced by an oral human rotavirus vaccine in gnotobiotic pigs[J]. Vaccine, 2012, 30(6): 1198-1207.

[6] 岳晓敬, 扶雄锋, 胡栾莎, 等. 复合益生菌发酵豆粕对断奶仔猪肠道形态和消化酶活性的影响 [J]. 中国畜牧杂志, 2016, 52(11): 49-54.

[7] ABE F, ISHIBASHI N, SHIMAMURA S. Effect of administration of *Bifidobacteria* and lactic acid bacteria to newborn calves and piglets[J]. Journal of Dairy Science, 1995, 78(12): 2838-2846.

[8] ESTIENNE M J, HARTSOCK T G. Effects of antibiotics and probiotics on suckling pig and weaned pig performance[J]. International Journal of Applied Research in Veterinary Medicine, 2005, 3(4): 303-308.

[9] 刘瑞丽, 李龙, 陈小莲, 等. 复合益生菌发酵饲料对肥育猪消化与生产性能的影响 [J]. 上海农业学报, 2011, 27(3): 121-125.

[10] 吴代圣, 吕李明, 丁建华. 复合益生菌发酵饲料饲喂生长育肥猪效果分析 [J]. 现代农业科技, 2011(1): 326, 328.

[11] 刘虎传, 张敏红, 冯京海, 等. 益生菌制剂对早期断奶仔猪生长性能和免疫指标的影响 [J]. 动物营养学报, 2012, 24(6): 1124-1131.

[12] 耿梅梅, 印遇龙, 孔祥峰, 等. 门静脉灌注葡萄糖对宁乡猪血液生化参数的影响 [J]. 安徽农业科学, 2010, 38(5): 2372-2375.

[13] 尹清强, 李小飞, 常娟, 等. 微生态制剂对哺乳和断奶仔猪生产性能的影响及作用机理研究 [J]. 动物营养学报, 2011, 23(4): 622-630.

[14] 唐晓玲, 刘振湘, 张石蕊, 等. 糖萜素对早期断奶仔猪血液生化指标及免疫机能的影响研究 [J]. 湖南环境生物职业技术学院学报, 2005, 11(3): 239-243.

[15] ZHOU H, WANG C Z, YE J Z, et al. Effects of dietary supplementation of fermented *Ginkgo biloba* L. residues on growth performance, nutrient digestibility, serum biochemical parameters and immune function in weaned piglets[J]. Animal Science Journal, 2015, 86(8): 790-799.

[16] 杨玉芬, 许道光, 王长康, 等. 不同含量的发酵豆粕对仔猪生长性能和血液指标的影响 [J]. 江西农业大学学报, 2014(3): 619-625.

[17] 高印, 王国军, 来航线, 等. 益生菌发酵苹果渣对断奶仔猪生长性能、血清生化指标和粪便微生物菌群的影响 [J]. 动物营养学报, 2016, 28(5): 1515-1524.

[18] FERNANDES C F, SHAHANI K M, AMER M A. Therapeutic role of dietary *Lactobacilli* and *Lactobacillic* fermented dairy productions[J]. FEMS Microbiology Reviews, 1987, 46(3): 343-356.

[19] 林谦, 戴求仲, 宾石玉, 等. 益生菌与酶制剂对黄羽肉鸡血液生化指标和免疫性能影响的协同效应研究 [J]. 饲料工业, 2012, 33(14): 31-36.

[20] 王国霞, 黄燕华, 周晔, 等. 乳酸菌对凡纳滨对虾幼虾生长性能、消化酶活性和非特异性免疫的影响 [J]. 动物营养学报, 2010, 22(1): 228-234.

[21] 董晓丽, 张乃锋, 周盟, 等. 复合菌制剂对断奶仔猪生长性能、粪便微生物和血清指标的影响 [J]. 动物营养学报, 2013, 25(6): 1285-1292.

[22] AFRC R. Probiotics in man animals[J]. Journal of Applied Bacteriology, 1989, 66(5): 365-378.

[23] 张董燕, 季海峰, 王四新, 等. 猪源唾液乳杆菌对生长猪生长性能、粪中微生物数量及血清指标的影响 [J]. 动物营养学报, 2014, 26(3): 725-731.

[24] 侯璐. 猪源粪肠球菌的特性及对仔猪生长性能和免疫力影响的研究 [D]. 硕士学位论文. 呼和浩特: 内蒙古农业大学, 2010: 40-41.

[25] MALLO J J, RIOPEREZ J, HONRUBIA P. The addition of *Enterococcus faecium* to diet improves piglet's intestinal microbiota performance[J]. Livestock Science, 2010, 133(1/2/3): 176-178.

[26] GIANG H H, VIET T Q, OGLE B, et al. Growth performance, digestibility, gut environment and health status in weaned piglets fed a diet supplemented with potentially probiotic complexes of lactic acid bacteria[J]. Livestock Science, 2010, 129(1/2/3): 95-103.

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