

Effects of Microecological Preparations and Compound Acidifiers on Production Performance, Serum Biochemical and Immune Indices, and Milk Composition in Lactating Sows (Postprint)

Authors: Wang Jingjing, Ren Hongli, Dong Jiaqi, Jin Sanjun, Li Yanfang, WU Hongzhi, Diao Xiping

Date: 2018-12-20T00:00:00+00:00

Abstract

This study aimed to investigate the effects of microecological preparation and compound acidifier on production performance, serum biochemical and immune parameters, and milk composition in lactating sows. A 2\$×\$2 factorial randomized design was employed, with the main effects being acidifier (0, 0.5%), microecological preparation (0, 200 mL/d), and their interaction. Twenty-four Landrace × Large White sows with similar parity and expected farrowing date were selected and randomly allocated to 4 groups (6 sows per group), which were fed the basal diet (control group), basal diet + 200 mL/d microecological preparation (microecological preparation group), basal diet + 0.5% compound acidifier (compound acidifier group), and basal diet + 200 mL/d microecological preparation + 0.5% compound acidifier (combination group), respectively. The preliminary feeding period lasted 7 d, followed by a 21-d formal experimental period. The results showed: 1) The combination group exhibited significantly higher average daily feed intake of sows, total milk yield, average individual piglet weight on day 21, and litter weaning weight compared with the control group ($P<0.05$); compared with the control group, each supplementation group showed an increasing trend in average individual piglet weight on days 1, 7, and 14, number of weaned live piglets, and average daily gain of piglets, but the differences were not significant ($P>0.05$). 2) On day 21 of the experiment, serum contents of total cholesterol, triglycerides, total protein, albumin, immunoglobulin A, and immunoglobulin G in the combination group were significantly higher than those in the control group ($P<0.05$). Serum urea nitrogen content in each supplementation group was lower than that in the control group, but the differences among groups were not significant ($P>0.05$). 3) Milk fat content in colostrum and mature milk, and lactose content in mature milk in each sup-

plementation group were significantly higher than those in the control group ($P < 0.05$), while milk protein content was also higher than that in the control group, but the difference was not significant ($P > 0.05$). It can be concluded that under the conditions of this experiment, dietary supplementation with microecological preparation and compound acidifier tended to improve production performance, serum biochemical and immune parameters in lactating sows, and could increase average daily feed intake, total milk yield, and serum contents of total cholesterol, triglycerides, total protein, albumin, immunoglobulin A, and immunoglobulin G; their combined use could partially improve milk composition.

Full Text

Effects of Probiotics and Compound Acidifier on Performance, Serum Biochemical and Immune Indices, and Milk Composition of Lactating Sows

WANG Jingjing, REN Hongli, *DONG Jiaqi*, JIN Sanjun, LI Yanfang, WU Hongzhi, DIAO Xinping

College of Animal Science and Technology, Northeast Agricultural University, Harbin 150030, China

Abstract

This experiment was conducted to evaluate the effects of dietary probiotics and compound acidifier on the performance, serum biochemical and immune indices, and milk composition of lactating sows. A 2×2 factorial randomized design was employed, with two levels of compound acidifier (0 and 0.5%) and two levels of probiotics (0 and 200 mL/d) as the main effects, allowing examination of their interaction. Twenty-four Landrace \times Large White sows with similar parity and expected farrowing dates were randomly allocated to four groups ($n = 6$): control (basal diet), probiotics (basal diet + 200 mL/d probiotics), acidifier (basal diet + 0.5% compound acidifier), and mixed (basal diet + 200 mL/d probiotics + 0.5% compound acidifier). The trial consisted of a 7-day pre-feeding period followed by a 21-day experimental period.

The results showed: (1) The mixed group exhibited significantly higher average daily feed intake (ADFI), total lactation yield, average piglet weight on day 21, and weaning litter weight compared to the control group ($P < 0.05$). While piglet weights on days 1, 7, and 14, number of piglets alive at weaning, and average daily gain showed increasing trends in all treatment groups, these differences were not statistically significant ($P > 0.05$). (2) On day 21, the mixed group had significantly elevated serum concentrations of total cholesterol, triglycerides, total protein, albumin, immunoglobulin A (IgA), and immunoglobulin G (IgG) relative to the control ($P < 0.05$). Serum urea nitrogen levels were lower in all treatment groups compared to control, though not significantly ($P > 0.05$).

(3) All treatment groups showed significantly higher milk fat content in both colostrum and milk, as well as higher lactose content in milk, compared to the control ($P < 0.05$). Milk protein content was also elevated in treatment groups but did not reach statistical significance ($P > 0.05$).

In conclusion, under the conditions of this study, dietary supplementation with probiotics and compound acidifier improved lactating sow performance and enhanced serum biochemical and immune indices, including ADFI, total lactation yield, and serum concentrations of total cholesterol, triglycerides, total protein, albumin, IgA, and IgG. The combination of both additives also partially improved milk composition.

Keywords: probiotics; compound acidifier; lactating sows; performance; serum biochemical and immune indices; milk composition

Introduction

Probiotics and compound acidifiers are natural, safe feed additives that function by reducing intestinal pH, proliferating beneficial bacteria, inhibiting harmful bacteria, regulating gut microbiota, improving nutrient digestibility, and enhancing digestive enzyme activity. Compound acidifiers represent one approach to increasing nutrient intake in lactating sows, as they reduce dietary alkalinity, increase acidity, improve feed utilization, enhance animal performance, protect gastrointestinal mucosal health, and strengthen immune function [1]. Probiotics are microbial preparations derived from normal microorganisms or growth-promoting microbes that are specially processed as viable organisms capable of regulating intestinal microecological balance, promoting beneficial microbial growth, inhibiting pathogen proliferation, and preventing disease [2].

Previous research has demonstrated synergistic effects of these additives. Chen et al. [3] found that combined supplementation of probiotics and acidifiers significantly increased serum IgA levels in weaned piglets, while acidifier alone increased beneficial gut bacteria and reduced harmful bacteria. Zhou et al. [4] reported that the combination improved laying hen health by enhancing antioxidant capacity and immune function. Although numerous studies have examined these additives individually, few have investigated their combined effects in lactating sows. Therefore, rational application of compound acidifiers and probiotics may represent an important strategy for improving swine health and immunity. However, varying compositions and combinations of these additives yield inconsistent results. This study investigated the effects of dietary probiotics, compound acidifier, and their combination on lactating sow performance, serum biochemical and immune indices, and milk composition to provide theoretical support for their application in sow nutrition and promote sustainable swine industry development.

Materials and Methods

1.1 Experimental Materials The compound acidifier, containing formic acid, acetic acid, propionic acid, butyric acid, lactic acid, and a buffer system, was provided by Chongqing Youbao Biotechnology Co., Ltd. The probiotic preparation, a mixture of lactic acid bacteria, yeast, and culture medium containing *Lactobacillus* (1×10^8 CFU/mL) and yeast (8×10^7 CFU/mL), was supplied by Shenzhen Baiaofei Biotechnology Co., Ltd.

1.2 Experimental Design and Animal Management A 2×2 factorial randomized design was used with two probiotic levels (0 and 200 mL/d) and two acidifier levels (0 and 0.5% in diet). The basal diet was formulated according to NRC (1998) standards as a corn-soybean meal diet; its composition and nutrient levels are shown in Table 1.

Twenty-four healthy Landrace \times Large White crossbred sows with similar parity and expected farrowing dates were randomly assigned to four groups ($n = 6$ per group): control (basal diet), probiotics (basal diet + 200 mL/d probiotics), acidifier (basal diet + 0.5% compound acidifier), and mixed (basal diet + 200 mL/d probiotics + 0.5% compound acidifier). The 28-day trial included a 7-day pre-feeding period (7 days before parturition) and a 21-day experimental period (from parturition to weaning). Sows were pre-fed the basal diet during the pre-trial period. Postpartum sows were fed restricted amounts initially using wet mash feeding with ad libitum water access. All sows were managed under identical housing conditions following the farm's standard management and immunization protocols. Piglets were weaned on day 21.

1.3 Measurement Indices

1.3.1 Performance Indices Daily feed intake was recorded to calculate average daily feed intake (ADFI). Litter size and weight were recorded within 12 h postpartum and on days 7, 14, and 21 to determine average piglet weight at different stages, average daily gain (ADG), birth litter weight, weaning litter weight, number of live-born piglets, and number of weaned piglets. Total lactation yield (TL) during the 21-day lactation period was calculated according to Lawlor et al. [5]:

$$\text{Total lactation yield (kg)} = \text{ADG of piglets} \times \text{Number of piglets per litter} \times \text{Lactation days} \times 4$$

Backfat thickness was measured on the day of parturition and day 21 using a backfat meter (6.5 cm from the dorsal midline at the last rib) to determine initial and final backfat thickness (average of three measurements per sow). Backfat loss was calculated as:

$$\text{Backfat loss} = \text{Initial backfat thickness} - \text{Final backfat thickness}$$

1.3.2 Serum Biochemical and Immune Indices On day 21, 10 mL of blood was collected from each sow's ear vein before morning feeding. After standing for 15 min, serum was separated by centrifugation at 3,000 rpm for 20 min and stored at -20°C. Serum concentrations of total protein, albumin, urea nitrogen, triglycerides, total cholesterol, IgG, IgA, and alkaline phosphatase activity were determined by enzyme-linked immunosorbent assay using commercial kits (Beijing Huaying Biotechnology Research Institute) according to manufacturer instructions.

1.3.3 Milk Composition Indices Colostrum (30 mL) was collected from anterior, middle, and posterior mammary glands at parturition. On day 11 of lactation, 2 mL of oxytocin was injected intravenously before morning feeding, and 30 mL of milk was collected from the three mammary regions. Samples were stored at -20°C for analysis of lactose (LA), milk fat (MF), and milk protein (MP) content.

1.4 Statistical Analysis Data were analyzed using SPSS 20.0 software with two-way ANOVA and Duncan's multiple comparison test. Results are expressed as "mean \pm standard deviation." Statistical significance was declared at $P < 0.05$ and extreme significance at $P < 0.01$.

Results

2.1 Effects on Lactating Sow Performance As shown in Table 2, the mixed group had significantly higher ADFI, total lactation yield, average piglet weight on day 21, and weaning litter weight compared to the control group ($P < 0.05$). While the probiotics and acidifier groups showed higher values for these parameters than the control, the differences were not significant ($P > 0.05$). No significant differences were observed among groups for piglet weight on days 1, 7, and 14, ADG, number of live-born piglets, birth litter weight, backfat loss, or number of weaned piglets ($P > 0.05$).

Main effect analysis revealed that dietary probiotics significantly increased total lactation yield and piglet ADG ($P < 0.05$), while compound acidifier significantly increased sow ADFI and weaning litter weight ($P < 0.05$). The interaction between probiotics and acidifier significantly affected piglet weight on day 1 ($P < 0.05$) but had no significant effects on piglet weight on days 7, 14, or 21, ADG, sow ADFI, total lactation yield, or number of weaned piglets ($P > 0.05$).

2.2 Effects on Serum Biochemical and Immune Indices As shown in Table 3, all treatment groups had significantly higher serum total cholesterol concentrations than the control group ($P < 0.05$), while serum urea nitrogen levels were lower in treatment groups but not significantly different ($P > 0.05$). The mixed and acidifier groups showed significantly higher serum triglyceride and albumin concentrations compared to control ($P < 0.05$), whereas the probiotics group did not differ significantly from control ($P > 0.05$). The mixed

group exhibited significantly higher alkaline phosphatase activity and IgA and IgG concentrations compared to control ($P < 0.05$). Serum total protein concentrations were higher in all treatment groups than in control but without statistical significance ($P > 0.05$).

Main effect analysis indicated that dietary probiotics significantly affected serum total cholesterol, albumin, IgA, and IgG concentrations ($P < 0.05$). Dietary acidifier significantly influenced alkaline phosphatase activity and serum concentrations of total cholesterol, triglycerides, albumin, IgA, and IgG ($P < 0.05$). The interaction between probiotics and acidifier significantly affected serum total cholesterol and alkaline phosphatase activity ($P < 0.05$) but had no significant effects on urea nitrogen, triglycerides, total protein, albumin, IgA, or IgG ($P > 0.05$).

2.3 Effects on Milk Composition As shown in Table 4, all treatment groups had significantly higher milk fat content in both colostrum and milk, as well as higher lactose content in milk, compared to the control group ($P < 0.05$). Milk protein content in colostrum and milk was also higher in treatment groups, with the mixed group showing the highest values, but differences were not statistically significant ($P > 0.05$).

Main effect analysis demonstrated that dietary probiotics significantly increased milk fat content in both colostrum and milk ($P < 0.05$), while compound acidifier significantly increased colostrum milk fat content ($P < 0.05$). The interaction between probiotics and acidifier had no significant effects on milk fat, protein, or lactose content in either colostrum or milk ($P > 0.05$).

Discussion

3.1 Effects on Lactating Sow Performance Sow lactation performance is a critical indicator of reproductive efficiency that directly affects offspring development and farm productivity. Peng et al. [6] reported that adding 4 kg/t acidifier to lactating sow diets significantly increased ADFI by 12.3% during lactation. Wang et al. [7] found that 0.20% sorbic acid supplementation significantly improved piglet ADG and weaning litter weight. Similarly, probiotics enhance animal performance. Lü et al. [8] demonstrated that probiotics significantly increased feed intake during lactation and improved live-born piglet numbers and birth weights. Huo et al. [9] observed that probiotic supplementation increased piglet birth weight and weaning weight by 8.63% and 7.55%, respectively. Liu et al. [10] reported that 200 g/t probiotics significantly increased sow ADFI and consequently improved piglet weaning weight. Our results align with these findings, showing that both acidifier and probiotics improved ADFI, total lactation yield, piglet weight on day 21, and weaning litter weight.

Several mechanisms may explain these effects. First, compound acidifiers can mask undesirable feed odors, and pigs' well-developed taste preference for acidic diets improves palatability and feed intake [11]. Increased feed intake directly

enhances milk production, thereby improving piglet weaning weight and survival rates. Yan et al. [12] found acidifiers more effective than sweeteners in increasing sow feed intake. Second, probiotic microorganisms such as lactic acid bacteria contain abundant nutrients and produce growth factor-like substances during fermentation or metabolism [13], which may promote hormones related to lactation, enhance mammary gland development and secretion, and provide adequate milk nutrition for piglets. Additionally, compound acidifiers reduce intestinal pH, inhibiting harmful bacteria and helping probiotic microorganisms establish dominant flora. The probiotic preparation used in this study contained acid-tolerant bacteria like lactic acid bacteria that proliferate under appropriate acidic conditions, while their acid-producing activity helps stabilize and enhance the acidifying effect of compound acidifiers in the digestive tract [14]. However, some studies have reported that citric acid alone had no significant effect on sow feed intake or weight gain [15]. Inconsistent results regarding acidifier effects on sow feed intake may be attributed to factors such as animal age, weaning time, acidifier type and inclusion level, diet composition, and dietary acid-binding capacity [16].

3.2 Effects on Serum Biochemical and Immune Indices Serum biochemical parameters reflect metabolic changes and organ function in response to stress [17]. Total protein provides a favorable internal environment for protein synthesis and animal growth. Zhu et al. [18] found that 1.0% citric acid supplementation in weaned piglet diets significantly increased serum total protein, albumin, and globulin concentrations. Our results are consistent, showing increased serum total protein in all treatment groups and significantly higher albumin in the mixed group.

Serum urea nitrogen accurately reflects protein metabolism and amino acid balance, with lower levels indicating better amino acid balance and protein deposition [19]. In this study, all treatment groups had reduced serum urea nitrogen, with the mixed group showing the lowest values, indicating that either individual or combined supplementation effectively promoted protein absorption and utilization while improving immune function.

Fallah et al. [20] reported that probiotics and acidifiers significantly reduced serum total cholesterol and triglyceride concentrations in piglets, while Brzóska et al. [21] found no significant effects of acidifiers on these parameters in broilers. Our results differ from these reports but align with Xiang [22], showing significantly increased serum triglycerides and total cholesterol on day 21 of lactation. This may be because compound acidifiers enhanced microbial fermentation in the intestine [23], producing more volatile fatty acids for triglyceride synthesis, while fatty acid transport requires substantial cholesterol. Additionally, increased serum triglycerides may be utilized for milk fat synthesis.

Alkaline phosphatase originates primarily from liver and bone tissues and is closely related to zinc and phosphorus metabolism and animal growth rate. The significantly higher alkaline phosphatase activity in the mixed group indicates

that combined supplementation promoted nutrient digestion and animal development.

Immunoglobulin G neutralizes viruses and facilitates phagocytosis, with its concentration largely reflecting immune capacity. Li et al. [24] reported that probiotics significantly increased serum IgA and IgG concentrations in growing pigs, consistent with Chen et al. [3] who found synergistic effects of combined probiotics and acidifiers on IgA and IgG in weaned piglets. Our results confirm that both additives individually and in combination significantly increased serum IgA and IgG concentrations, thereby enhancing immunity. This may occur because probiotic bacteria like lactic acid bacteria and yeast adjust gastrointestinal microecological balance, increase beneficial flora, inhibit or kill harmful bacteria, and strengthen immunity [25]. Compound acidifiers may also transform harmful substances in the intestine through oxidation, reduction, and fermentation to produce cellular immune factors, thereby improving immunity.

3.3 Effects on Milk Composition Milk is the direct energy and protein source for suckling piglets, and sow milk quality critically affects piglet development, immunity, and weaning weight [26]. Several studies have reported positive effects of acidifiers on milk composition. Dietary citric acid (1.5%) during late gestation and lactation significantly increased colostrum protein content [14]. Øverland et al. [27] found that potassium diformate (0.8% and 1.2%) from mating onward tended to increase milk fat content during lactation. Wang et al. [28] reported that potassium butyrate supplementation during late gestation significantly increased milk fat and protein content on days 1 and 14 of lactation, as well as lactose content on day 14. Coated sodium butyrate (500 mg/kg) increased milk fat and total solids by 29.75% and 10.94%, respectively [29]. Liu et al. [10] found that probiotics significantly increased milk protein, fat, and lactose content on days 1 and 14 of lactation.

Our results partially align with previous studies, showing that combined supplementation significantly increased milk fat in colostrum and milk and lactose in milk, with elevated milk protein content (highest in the mixed group) that did not reach significance. The lack of significant improvement in milk protein content in the mixed group may be because the 0.5% acidifier rapidly reduced intestinal pH, potentially compromising the proliferation conditions for lactic acid bacteria in the probiotic preparation, which require optimal pH ranges. Additionally, differences in additive composition, feeding methods, and individual animal variation may have prevented additive effects. Since supplementation began only 7 days before parturition and milk samples were collected on day 11 of lactation, longer supplementation periods might yield more pronounced increases in milk protein. Therefore, further research is needed to determine optimal dosage combinations and application stages for compound acidifiers and probiotics.

Conclusion

Under the conditions of this study, daily supplementation with probiotics and compound acidifier improved lactating sow performance and enhanced serum biochemical and immune indices, including ADFI, total lactation yield, and serum concentrations of total cholesterol, triglycerides, total protein, albumin, IgA, and IgG. The combination of both additives also partially improved milk composition.

References

- [1] KIM Y Y, KIL D Y, OH H K, et al. Acidifier as an alternative material to antibiotics in animal feed[J]. *Asian-Australasian Journal of Animal Sciences*, 2005, 18(7): 1048-1060.
- [2] HUO Yongjiu, ZHANG Yanyun, SHI Qingqing, et al. Effects of Bacillus 1259 preparation on growth performance and ammonia production in manure of growing-finishing pigs[J]. *Jiangsu Agricultural Sciences*, 2012, 40(2): 159-161.
- [3] CHEN Daiwen, ZHANG Keying, WANG Wanxiang, et al. Effects of acidifier, probiotics and oligosaccharides on fecal microflora and immune function in weaned piglets and their interaction effects[J]. *Chinese Journal of Animal Nutrition*, 2006, 18(3): 172-178.
- [4] ZHOU Ling, DING Xuemei, LUO Yuheng, et al. Effects of compound acidifier and microecological preparation on production performance, blood biochemical indices, antioxidant indices and Salmonella infection in laying hens[J]. *Chinese Journal of Animal Nutrition*, 2016, 28(8): 2571-2580.
- [5] LAWLOR P G, LYNCH P B, GARDINER G E, et al. Effect of liquid feeding weaned pigs on growth performance to harvest[J]. *Journal of Animal Science*, 2002, 80(7): 1725-1735.
- [6] PENG Yan, XIE Fei. Effect of acidifier on feed intake of lactating sows[J]. *Feed China*, 2013(13): 29-31.
- [7] WANG Haifeng, FANG Xinling, ZHU Xiaotong, et al. Effects of sorbic acid supplementation in sow diets on performance and serum biochemical indices of lactating sows and suckling piglets[J]. *Chinese Journal of Animal Nutrition*, 2013, 25(1): 118-125.
- [8] LÜ Wei, WEI Yuming, QI Ming, et al. Effects of several compound microecological feed additives on reproductive performance of sows and growth performance of nursery and finishing pigs[J]. *Journal of Animal Science and Veterinary Medicine*, 2016, 35(2): 4-7, 12.
- [9] HUO Jun, SONG Yuzhen, DONG Qing, et al. Effect of dietary microecological preparation on reproductive performance of sows[J]. *Jiangsu Agricultural Sciences*, 2013, 41(12): 220-222.

- [10] LIU Aijun, YIN Wang. Effects of compound microecological preparation on milk composition and reproductive performance of lactating sows[J]. *Feed Research*, 2014(19): 26-28.
- [11] COLE D J, BEAL R M, LUSCOMBE J R. The effect on performance and bacterial flora of lactic acid, propionic acid, calcium propionate and calcium acrylate in the drinking water of weaned pigs[J]. *Veterinary Record*, 1968, 83(18): 459-464.
- [12] YAN Fuyong, LIU Yunhua, CAO Xia, et al. Effects of sweetener and acidifier on feed intake and lactation capacity of lactating sows[J]. *China Feed Additive*, 2010(1): 20-22.
- [13] PAN Yongrong, ZHANG Junfeng, JIANG Yunyong. Application of microecological preparations in pig production[J]. *Modern Animal Husbandry and Veterinary Medicine*, 2010(8): 34-35.
- [14] XU Gang. Study on application effects and combination effects of four green feed additives for broilers[D]. Master's thesis. Yangling: Northwest A&F University, 2007.
- [15] LIU S T, HOU W X, CHENG S Y, et al. Effects of dietary citric acid during gestation and lactation on sow performance, digestibility of calcium and phosphorus, milk composition and immunoglobulin[J]. *Animal Science and Technology*, 2014, 191(5): 67-75.
- [16] RADECKI S V, JUHL M R, MILLER E R. Fumaric and citric acids as feed additives in starter pig diets: effect on performance and nutrient balance[J]. *Journal of Animal Science*, 1988, 66(10): 2598-2605.
- [17] DONG Shuli, WANG Zhanbin, LEI Xueqin, et al. Effects of heat stress on blood biochemical indices in animals[J]. *Livestock Ecology*, 2004, 25(2): 54-56.
- [18] ZHU Mengling, CHEN Chao, MA Guofu, et al. Effects of organic acids on growth performance and serum biochemical indices in Landrace \times Meishan weaned piglets[J]. *Journal of Anhui Agricultural Sciences*, 2010, 38(33): 18861-18862, 18865.
- [19] WU G Y, BAZER F W, DAVIS T A, et al. Arginine metabolism and nutrition in growth, health and disease[J]. *Amino Acids*, 2009, 37(1): 153-168.
- [20] FALLAH R, REZAEI H. Effect of dietary prebiotic and acidifier supplementation on the growth performance, carcass characteristics and serum biochemical parameters of broilers[J]. *Journal of Cell and Animal Biology*, 2013, 7(2): 21-24.
- [21] BRZÓSKA F, ŚLIWIŃSKI B, MICHALIK-RUTKOWSKA O. Effect of dietary acidifier on broiler chickens: growth, mortality, post-slaughter parameters and meat composition[J]. *Annals of Animal Science*, 2013, 13(1): 85-96.
- [22] XIANG Xing. Effects of dietary acidifier on reproductive performance, milk composition and immune indices of sows[D]. Master's thesis. Ya'an: Sichuan

Agricultural University, 2015.

[23] CHEN Baojiang, JING Cui, YU Huimin, et al. Effects of acidifier on intestinal mucosal morphology, microflora and volatile fatty acid production in early-weaned piglets[J]. China Animal Husbandry and Veterinary Medicine, 2011, 38(10): 23-26.

[24] LI Rui, HOU Gaifeng, WU Liyang, et al. Effects of microecological preparation on growth performance, nitrogen and phosphorus excretion and serum immune indices in growing pigs[J]. Journal of Livestock Ecology, 2013, 34(6): 66-71.

[25] GU Jin, ZHANG Shiyuan, ZHOU Weiren, et al. Effects of compound microecological preparation on growth performance and some blood biochemical indices of Qingjiaoma chickens[J]. China Poultry, 2010, 32(5): 34-36.

[26] BOYD R D, KENSINGER R S. Metabolic precursors for milk synthesis[M]// VERSTEGEN M W, MOUGHAN P J, SCHRAMA H W, et al. The lactating sow. Netherlands: Wageningen Press, 1998.

[27] ØVERLAND M, BIKKER P, FLEDDERUS J. Potassium diformate in the diet of reproducing sows: effect on performance of sows and litters[J]. Livestock Science, 2009, 122(2/3): 241-247.

[28] WANG Erhong, WU De, FANG Zhengfeng, et al. Effects of dietary potassium butyrate on reproductive performance, blood biochemical indices and milk composition of lactating sows[J]. Chinese Journal of Animal Nutrition, 2010, 22(5): 1367-1373.

[29] FANG Cuilin. Effects of coated sodium butyrate on performance of sows and their offspring[D]. Master's thesis. Hangzhou: Zhejiang University, 2014.

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

Source: ChinaXiv – Machine translation. Verify with original.