Effects of Different Formulations of Acidifiers on Production Performance, Colostrum Composition, and Gut Microbiota Structure in Lactating Sows (Postprint)

Authors: Zhang Jingjing, Liu Gengshou, Li Wei, Song Yizhen, Gaofei

Date: 2017-10-23T00:00:00+00:00

Abstract

This experiment aimed to compare the effects of two different formulations of acidifiers on the productive performance, colostrum composition, and intestinal microbiota structure of lactating sows. Thirty Landrace × Yorkshire crossbred sows with similar body condition and expected farrowing dates, ranging from parity 2 to 4, were selected and randomly divided into 3 groups with 10 replicates per group and 1 sow per replicate. During the experimental period, sows in each group were fed the basal diet (control group), basal diet + 0.3% adsorbent-type acidifier (Group A), or basal diet + 0.1% microencapsulated acidifier (Group B), respectively. The preliminary period lasted 7 days (7 days before farrowing), and the formal experimental period lasted 26 days (from farrowing to the end of lactation). The results showed that compared with the control group, the average daily feed intake of sows during lactation in Groups A and B increased by 4.9% ($P > 0.05$) and 5.3% ($P > 0.05$), respectively, and the average weaning weight of piglets increased by 2.6% ($P > 0.05$) and 7.4% ($P < 0.05$), respectively. The contents of milk fat, milk protein, urea nitrogen, immunoglobulin G, and immunoglobulin A in sow colostrum of Groups A and B were higher than those of the control group ($P > 0.05$), while the lactose content was lower than that of the control group ($P > 0.05$). Compared with the control group, dietary protein digestibility of sows in Group B was significantly improved ($P < 0.05$), and the fecal Escherichia coli count was significantly reduced ($P < 0.05$); the fecal Escherichia coli count of sows in Group A was also significantly reduced ($P < 0.05$). These results indicate that microencapsulated acidifier has certain efficacy in improving piglet weaning weight, dietary protein digestibility of lactating sows, and intestinal microbiota structure, while adsorbent-type acidifier has certain efficacy in improving the intestinal microbiota structure of lactating sows.

Full Text

Effects of Different Formulation Acidifiers on Performance, Colostrum Composition, and Intestinal Microflora Structure of Lactating Sows

ZHANG Jingjing, LIU Genshou, LI Wei, SONG Yizhen, GAO Fei
(Menon Animal Nutrition Technology Co., Ltd., Shanghai 201807, China)

Abstract: This experiment aimed to compare the effects of two different formulation acidifiers on the performance, colostrum composition, and intestinal microflora structure of lactating sows. Thirty Landrace × Large White crossbred sows (parity 2–4) with similar body condition and expected farrowing dates were randomly allocated to 3 groups with 10 replicates per group (1 sow per replicate). During the trial, sows were fed either a basal diet (control group), the basal diet supplemented with 0.3% adsorption-type acidifier (Group A), or the basal diet supplemented with 0.1% microencapsulated acidifier (Group B). The study consisted of a 7-day pre-trial period (7 days before parturition) and a 26-day formal experimental period (from parturition to the end of lactation). The results showed that compared with the control group, the average daily feed intake during lactation in Groups A and B increased by 4.9% ($P > 0.05$) and 5.3% ($P > 0.05$), respectively, while the average weaning weight of piglets increased by 2.6% ($P > 0.05$) and 7.4% ($P < 0.05$), respectively. The colostrum of sows in Groups A and B exhibited higher contents of milk fat, milk protein, urea nitrogen, immunoglobulin G, and immunoglobulin A ($P > 0.05$) but lower lactose content ($P > 0.05$) compared with the control group. Group B showed significantly improved dietary protein digestibility ($P < 0.05$) and significantly reduced fecal *Escherichia coli* counts ($P < 0.05$) relative to the control group, while Group A also significantly decreased fecal *E. coli* counts ($P < 0.05$). These findings indicate that microencapsulated acidifier is effective in improving piglet weaning weight, dietary protein digestibility, and intestinal microflora structure of lactating sows, whereas adsorption-type acidifier can improve the intestinal microflora structure of lactating sows.

Keywords: acidifier; formulation; lactating sows; performance; colostrum composition; intestinal microflora structure

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Insufficient nutrient intake in lactating sows represents a major challenge in modern swine production, leading to compromised reproductive performance [1], primarily manifested as inadequate milk production that negatively impacts piglet growth and pre-weaning survival rates [2]. Additionally, due to insufficient nutrient intake, sows typically experience significant body weight loss during lactation, resulting in deteriorated body condition, prolonged weaning-to-estrus interval, anestrus, and potentially shortened breeding lifespan.

One approach to enhance nutrient intake in lactating sows is dietary acidifier supplementation, which can stimulate intestinal motility, improve feed digestibility, and increase milk yield while effectively enhancing the immunity of both sows and piglets [3]. Numerous studies have demonstrated that increasing dietary protein levels during lactation reduces sow weight loss [4-6]. Acidifiers are widely used in livestock production, primarily to improve protein utilization and modulate intestinal microbial communities [7-9]; however, whether enhanced protein digestibility in lactating sows can increase feed intake remains unreported. Research on weaned piglets has shown that dietary acidifiers effectively improve feed intake [10-11], presumably by enhancing the digestibility of dietary protein and other nutrients [12]. Compared with piglet studies, research on acidifier application in lactating sows is relatively limited. Kluge et al. [13] reported that dietary supplementation with 2% benzoic acid improved nutrient utilization in lactating sows, while Devi et al. [3] found that acidifiers affected feed efficiency and improved intestinal microflora in lactating sows. Studies in piglets have indicated that different processing methods of acidifiers yield varying effects on growth performance, with protected or slow-release acidifiers demonstrating superior efficacy compared to conventional adsorption-mixed types [10]; however, no such reports exist for lactating sows.

This study investigated the effects of two different formulation acidifiers on feed intake, piglet birth and weaning weights, colostrum composition, and fecal *E. coli* and *Lactobacillus* counts in lactating sows, aiming to provide practical guidance for feed and animal nutrition professionals in selecting effective acidifier products for lactating sow diets.

1.1 Test Materials

The acidifiers used in this experiment were processed using two technologies: adsorption-type and microencapsulated. The main ingredients included fumaric acid (24.33%), lactic acid (4.49%), malic acid (4.87%), benzoic acid (4.87%), formic acid (6.92%), and propionic acid (3.09%), with the remainder being silicon dioxide and palm oil. Acidifier samples were processed and manufactured by Menon Animal Nutrition Technology Co., Ltd.

1.2 Experimental Design and Management

Thirty Landrace × Large White crossbred sows (parity 2–4) were selected and divided into 3 groups (10 replicates per group, 1 sow per replicate) based on similar expected farrowing dates and balanced body condition, parity, weight, and backfat thickness. The three groups were: control group (basal diet only), Group A (basal diet + 0.3% adsorption-type acidifier), and Group B (basal diet + 0.1% microencapsulated acidifier). The supplementation levels were determined based on preliminary trials that evaluated different inclusion rates of both acidifier types, revealing that 0.3% adsorption-type and 0.1% microencapsulated acidifiers produced the most significant effects on lactating sow performance.

The trial was conducted at a pig farm operated by Changzhou Menon Agri-

Tech Co., Ltd. Sows in late gestation were fed the experimental diets for one week before farrowing as a pre-feeding adaptation. After parturition, individual piglet birth weights were measured and litters were standardized across groups (ensuring consistent piglet numbers and birth weights) before commencing the formal experiment. Feed was provided at 04:00 and 14:00 daily using wet-mash feeding (acidifiers were added to the basal diet at the specified proportions before feeding), with free access to water. All sows were managed under identical housing and management conditions according to the farm' s standard operating and immunization procedures. All piglets were weaned at 26 days of age and weaning weights were recorded. The total trial duration was 33 days, comprising a 7-day pre-trial period (7 days before parturition) and a 26-day formal experimental period (from parturition to the end of lactation).

1.3 Basal Diet

The basal diet was formulated according to NRC (1998) nutrient requirements for lactating sows. Its composition and nutrient levels are presented in Table 1 .

1.4 Sample Collection

1.4.1 Colostrum Samples

On the day of parturition, colostrum was collected from three teats (anterior, middle, and posterior) of each sow, with 5 mL per sow, and stored at -20 °C.

1.4.2 Fecal Samples

From days 15–17 of lactation, fecal samples were collected from sows in each group using the partial collection method for three consecutive days (under normal feeding conditions). Representative, clean samples free of sand particles were collected, treated with 10% hydrochloric acid for nitrogen fixation, and stored at 0–5 °C for subsequent analysis.

1.5 Measurement Indicators

1.5.1 Performance Metrics

Individual piglet weights were recorded after parturition to calculate average birth weight, along with total born, born alive, and healthy piglet numbers. Daily feed intake of lactating sows was recorded to calculate average daily feed intake during lactation (from parturition to day 26). At weaning (day 26), piglet weights and numbers were recorded to calculate average weaning weight.

1.5.2 Dietary Protein Digestibility

Protein digestibility was determined using the hydrochloric acid-insoluble ash method.

1.5.3 Colostrum Composition

Milk fat, protein, and lactose contents were analyzed using a MilkoScanTM

FT2 multifunctional dairy analyzer. Urea nitrogen content was determined by Shanghai Bright Holstein Co., Ltd.

1.5.4 Colostrum Immunological Indices

Immunoglobulin G (IgG) and immunoglobulin A (IgA) concentrations were measured by enzyme-linked immunosorbent assay (ELISA) following the kit instructions. Kits were purchased from Shanghai Lanji Biotechnology Co., Ltd.

1.5.5 Total Bacteria, *E. coli*, and *Lactobacillus* Counts in Feces

Total DNA was extracted from fecal samples using a commercial kit. Based on gene sequences published in NCBI GenBank, upstream and downstream primers for 16S rRNA of different bacteria were designed using Primer Premier 5.0 software (Table 2). Fluorescence quantitative PCR was employed to compare bacterial population changes [14].

1.6 Statistical Analysis

Experimental data were pre-processed using Excel 2010 and analyzed by one-way ANOVA using SPSS 17.0 statistical software. Results are expressed as means ± standard deviation. Duncan' s multiple range test was used for post-hoc comparisons, with $P < 0.05$ considered statistically significant.

2 Results

2.1 Effects of Different Formulation Acidifiers on Lactating Sow Performance

As shown in Table 3 , the average daily feed intake during lactation in Groups A and B increased by 4.9% ($P > 0.05$) and 5.3% ($P > 0.05$) compared with the control group, respectively, with no significant difference between Groups A and B ($P > 0.05$). Group A increased piglet average birth weight and weaning weight by 3.2% ($P > 0.05$) and 2.6% ($P > 0.05$), respectively, while Group B increased these parameters by 2.4% ($P > 0.05$) and 7.4% ($P < 0.05$), respectively, compared with the control group. Piglet weaning weight in Group B was 4.8% higher than in Group A ($P > 0.05$).

2.2 Effects of Different Formulation Acidifiers on Dietary Protein Digestibility in Lactating Sows

Table 4 shows that dietary protein digestibility in Group A was higher than in the control group but the difference was not significant ($P > 0.05$). Group B exhibited higher protein digestibility than both the control group and Group A, with a statistically significant difference compared with the control group ($P < 0.05$).

2.3 Effects of Different Formulation Acidifiers on Colostrum Composition of Lactating Sows

As presented in Table 5 , Groups A and B showed higher colostral milk fat, protein, and urea nitrogen contents (P > 0.05) but lower lactose content (P > 0.05) compared with the control group. IgA and IgG concentrations in colostrum were also higher in Groups A and B (P > 0.05). No significant differences were observed between Groups A and B in any colostrum component (P > 0.05).

2.4 Effects of Different Formulation Acidifiers on Total Bacteria, *E. coli*, and *Lactobacillus* Counts in Sow Feces

Table 6 demonstrates that total bacterial and *Lactobacillus* counts in sow feces were lower in Groups A and B (P > 0.05), while *E. coli* counts were significantly reduced (P < 0.05) compared with the control group. The *Lactobacillus*/*E. coli* ratio showed an increasing trend in both treatment groups (P > 0.05).

3 Discussion

3.1 Effects of Different Formulation Acidifiers on Lactating Sow Performance

Low effective nutrient intake in lactating sows negatively affects piglet growth performance and compromises sow reproductive performance and economic efficiency in pig production. Postpartum sows require substantial milk production to nourish piglets; insufficient nutrient intake fails to meet lactation demands, making effective nutrient intake crucial in swine production. Liu et al. [15] reported that dietary supplementation with 0.5%, 1.0%, and 1.5% citric acid improved feed intake in lactating sows and enhanced piglet weaning weight. The current study found that both adsorption-type and microencapsulated acidifiers increased average daily feed intake during lactation, consistent with Liu et al. [15]. Furthermore, both acidifier formulations improved dietary protein digestibility, with the microencapsulated type showing significantly higher protein digestibility than the control group. This may be attributed to the sustained release of microencapsulated acidifiers not only in the stomach but also throughout the intestinal tract, promoting digestive enzyme secretion and enhancing protein digestibility. Additionally, both acidifier types increased piglet weaning weight, with the microencapsulated acidifier group showing significantly higher weaning weight than the control group. These results demonstrate that dietary acidifier supplementation in lactating sows can improve feed intake, protein digestibility, and piglet weaning weight, with microencapsulated acidifiers exhibiting superior efficacy.

3.2 Effects of Different Formulation Acidifiers on Colostrum Composition

Colostrum serves two critical biological functions in newborn piglets: nutrition and immunity. Colostrum contains abundant energy and bioactive compounds, with higher concentrations of dry matter, protein, fat, and minerals than mature milk, and smaller fat globules that facilitate intestinal absorption [16]. Newborn piglets have limited energy reserves and require substantial energy to adapt to environmental changes, making sow milk the primary energy source during the first 1–2 weeks and pre-weaning period. Therefore, piglet growth performance is directly related to sow milk yield and quality. Previous research found that dietary supplementation with 1.5% citric acid during late gestation and lactation significantly increased colostral protein content [15]. The current study observed an increasing trend in colostral protein and fat contents following acidifier supplementation, consistent with Liu et al. [15]. Since acidifiers were introduced 7 days before parturition in this trial, extended supplementation duration might yield more pronounced increases in colostral protein and fat contents.

The porcine placenta is epitheliochorial, preventing maternal antibody transfer to fetuses; thus, colostrum represents the sole source of passive immunity for newborn piglets. Sow colostrum contains three immunoglobulins: IgM, IgG, and IgA. IgG content correlates with piglet susceptibility to intestinal and respiratory diseases—piglets acquiring sufficient maternal IgG exhibit lower disease incidence and mortality [17]. IgA provides mucosal protection in the intestine, reducing *E. coli* infection [18]. Devillers et al. [19] demonstrated that colostrum intake is the primary determinant of piglet survival, influencing piglet viability through energy provision and immune protection while potentially exerting long-term effects on growth and immunity. Therefore, immunoglobulin concentration in colostrum is crucial for piglet health. This study found that dietary acidifier supplementation elevated colostral IgG and IgA concentrations, with microencapsulated acidifiers producing higher IgG levels than the adsorption type. These results suggest that acidifier supplementation enhances colostral IgG and IgA contents, possibly by increasing secretion from IgG- and IgA-producing cells in the mammary gland, though the exact mechanism requires further investigation.

3.3 Effects of Different Formulation Acidifiers on Intestinal Microflora Structure

The gastrointestinal tract harbors a large microbial community that plays vital roles in maintaining animal health, nutrient utilization, and colonization resistance [20]. While intestinal microflora structure is generally stable in adult animals, the distinct physiological stages of gestation, parturition, and lactation in sows disrupt this balance. Newborn piglets are sterile at birth and acquire their initial bacteria from sow feces [21]. Li et al. [22] reported that protected organic acids reduced fecal *E. coli* counts in weaned piglets. The current study similarly found that both acidifier formulations significantly decreased fecal *E.*

coli counts in lactating sows, consistent with Li et al. [22]. This indicates that dietary acidifiers release in the intestinal tract, lowering luminal pH and reducing acid-sensitive *E. coli* populations. Ahmed et al. [7] observed that acidifiers not only decreased *E. coli* but also increased *Lactobacillus* counts in weaned piglet feces. However, this study did not find increased *Lactobacillus* counts, though the *Lactobacillus*/*E. coli* ratio showed an upward trend, possibly due to the more complex intestinal microflora structure in lactating sows compared with piglets. These results demonstrate that acidifiers can modify intestinal pH and reduce *E. coli* populations, allowing *Lactobacillus* to become the dominant genus. As beneficial bacteria in the porcine intestine, *Lactobacillus* improves microecological balance. Therefore, dietary acidifier supplementation can enhance intestinal microflora structure in lactating sows.

4 Conclusion

Dietary supplementation with adsorption-type acidifier significantly reduced fecal *E. coli* counts and improved intestinal microflora structure in lactating sows. Microencapsulated acidifier significantly increased piglet weaning weight, improved dietary protein digestibility, and significantly decreased fecal *E. coli* counts, thereby enhancing sow performance and intestinal microflora structure. Microencapsulated acidifier demonstrated more pronounced effects on lactating sow performance than the adsorption type, proving more effective in improving piglet weaning weight and sow protein digestivity while requiring lower inclusion rates. Therefore, microencapsulated acidifier is recommended for lactating sow diets.

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