Effects of Oligochitosan on Reproductive Performance, Lactation Performance, and Plasma Biochemical Indices in Sows: Postprint

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Abstract

This experiment aimed to investigate the effects of dietary chitosan oligosaccharide supplementation on reproductive performance, lactation performance, and plasma biochemical indices in sows. Twenty-four healthy Large White sows with similar parity, body weight, and expected farrowing date were selected and randomly allocated to 3 groups with 8 replicates per group and 1 sow per replicate. The control group was fed a basal diet, while Groups I and II were fed the basal diet supplemented with 50 and 100 g/t chitosan oligosaccharide, respectively. The experiment commenced on day 85 of gestation and concluded on day 21 of lactation. The results showed: 1) Compared with the control group, dietary chitosan oligosaccharide supplementation significantly increased the number of healthy piglets and average daily feed intake during lactation ($P<0.05$), significantly reduced the duration of farrowing ($P<0.05$), and tended to improve sow constipation and decrease backfat thickness loss. Compared with the control group, Group I exhibited a significant increase in litter birth weight ($P<0.05$), while Group II showed a significant increase in milk yield during lactation ($P<0.05$). 2) Compared with the control group, Groups I and II demonstrated significantly increased milk fat content in colostrum ($P<0.05$), while Group I showed significantly increased urea nitrogen (UN) content in colostrum and arginine, total amino acids, and limiting amino acids contents in mature milk ($P<0.05$). 3) The plasma glutamic-pyruvic transaminase (GPT) activity in Groups I and II was significantly lower than that in the control group ($P<0.05$), while no significant differences were observed among groups in plasma alkaline phosphatase (ALP) and lactate dehydrogenase (LDH) activities or in total protein (TP), albumin (ALB), UN, triglyceride (TG), total cholesterol (CHO), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) contents ($P>0.05$). In conclusion, dietary chitosan oligosaccharide supplementation exerted beneficial effects on both reproductive and lactation performance in sows. Based on the comprehensive results of this study, 50 g/t chitosan oligosaccharide represents the optimal supplementation level in sow diets.

Full Text

Effects of Oligo-chitosan on Reproduction Performance, Lactation Performance and Plasma Biochemical Parameters of Sows

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Abstract

This study was conducted to investigate the effects of dietary oligo-chitosan on reproduction performance, lactation performance, and plasma biochemical parameters of sows. Twenty-four healthy Yorkshire sows with similar parity, body weight, and expected farrowing date were randomly assigned to three groups, with eight replicates per group and one sow per replicate. Sows in the control group were fed a basal diet, while those in experimental groups I and II received the basal diet supplemented with 50 and 100 g/t oligo-chitosan, respectively. The trial period spanned from day 85 of gestation to day 21 postpartum.

The results showed that: 1) Compared with the control group, dietary oligo-chitosan supplementation significantly increased the number of healthy piglets per litter and the average daily feed intake (ADFI) during lactation ($P<0.05$), while significantly reducing farrowing duration ($P<0.05$). Additionally, oligo-chitosan tended to improve constipation and decrease backfat thickness loss in sows. Specifically, the birth litter weight in experimental group I was significantly higher than that in the control group ($P<0.05$), and the total milk yield during lactation in experimental group II was significantly increased ($P<0.05$). 2) The milk fat content in colostrum was significantly elevated in both experimental groups I and II compared to the control group ($P<0.05$). Furthermore, experimental group I showed significantly increased urea nitrogen (UN) content in colostrum and significantly higher concentrations of arginine, total amino acids, and limiting amino acids in milk ($P<0.05$). 3) Plasma glutamic-pyruvic transaminase (GPT) activity was significantly lower in both experimental groups I and II relative to the control group ($P<0.05$). However, no significant differences were observed among groups in plasma alkaline phosphatase (ALP), lactate dehydrogenase (LDH) activities, or in total protein (TP), albumin (ALB), UN, triglyceride (TG), total cholesterol (CHO), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) concentrations (P>0.05).

In conclusion, dietary oligo-chitosan supplementation promotes both reproduction and lactation performance in sows. Based on the comprehensive results of this study, the optimal supplementation level of oligo-chitosan in sow diets is 50 g/t.

Key words: oligo-chitosan; sows; reproduction performance; lactation performance; plasma biochemical parameters

Introduction

Sows represent the core and foundation of pig production operations, with their reproductive performance serving as a critical indicator of productivity in intensive pig farms. The health status of sows directly determines the health of piglets and finishing pigs, while their production level and reproductive performance fundamentally dictate the economic efficiency of the entire operation. Research has demonstrated that metabolic pathways in pregnant animals differ from those in non-pregnant animals, with these differences becoming more pronounced as gestation advances. During late gestation, the rapid development of fetuses dramatically increases demands for oxygen and nutrients, imposing severe metabolic burdens on the dam and predisposing her to oxidative stress. The free radicals generated through metabolism can damage placental villi, leading to abnormalities in villous cell membranes, mitochondrial membranes, and placental function. These disruptions affect fetal development in utero, reduce sow lactation performance and immune function, and severely compromise sow health, longevity, and offspring development. Therefore, enhancing the immune function of sows during late gestation is of paramount importance.

Oligo-chitosan refers to chitosan degraded through enzymatic, chemical, or physical methods. Due to its low degree of polymerization and relatively small molecular weight, oligo-chitosan possesses physiological and pharmacological activities that high-molecular-weight chitosan lacks, with pharmacological activity 14 times greater than that of equivalent-weight chitosan. Low-degree-of-polymerization (2–10), water-soluble oligo-chitosan is called chitosan oligosaccharide, while material with a degree of polymerization above 20 that is not readily water-soluble is termed low-molecular-weight chitosan. Studies have shown that as a novel feed additive, oligo-chitosan exhibits various biological activities including hypolipidemic, antioxidant, antimicrobial, immune-enhancing, and gut health-improving effects. Current research on oligo-chitosan applications has primarily focused on its effects on growth performance and immune function, lipid metabolism, antioxidant capacity, and muscle development in young livestock. However, reports on the application of oligo-chitosan in sow diets remain extremely limited. This experiment was designed to investigate the effects of oligo-chitosan supplementation in late-gestation sow diets on reproductive performance, lactation performance, and plasma biochemical parameters, thereby providing a theoretical basis for its rational application in sow nutrition.

1.1 Experimental Materials

Oligo-chitosan was produced by Jiaxing Kerui Biotechnology Co., Ltd., with an average relative molecular weight of 2.5×10^{4}, deacetylation degree >85%, purity >95%, and particle size of approximately 20 m.

1.2 Experimental Animals and Design

Twenty-four healthy Yorkshire sows with similar parity, body weight, and expected farrowing date were selected and randomly allocated to three groups, with eight replicates per group and one sow per replicate. The control group received a basal diet, while experimental groups I and II were fed the basal diet supplemented with 50 and 100 g/t oligo-chitosan, respectively. The experimental period commenced on day 85 of gestation and concluded on day 21 postpartum (piglet weaning).

1.3 Experimental Diets

From day 85 of gestation, experimental sows were fed lactation diets. The basal diet was formulated according to NRC (2012) nutrient requirements combined with the actual conditions of the experimental farm. The composition and nutrient levels are presented in Table 1 . Diets were manufactured as pellets one week before the experiment began to maintain freshness.

Table 1 Composition and nutrient levels of the basal diet (air-dry basis), %

Ingredients	Content	Nutrient levels[2]	Content
Corn		Digestible energy (DE)/(MJ/kg)	
Soybean meal		Crude protein (CP)	
Wheat bran		Calcium (Ca)	
Extruded soybean		Total phosphorus (TP)	
Fish meal		Available phosphorus (AP)	
Oil meal		Total lysine (T-Lys)	
Glucose		Methionine + Cysteine (Met+Cys)	
Premix[1]		Total threonine (T-Thr)	
Total		Total tryptophan (T-Trp)	
		Total valine (T-Val)	

[1]Premix provided the following per kg of diet: Fe 80 mg, Mn 45 mg, Zn 100 mg, Cu 20 mg, I 0.70 mg, Se 0.25 mg, VA 10,000 IU, VD_3 2,500 IU, VE 100 IU, VK_3 10 IU, VB_1 4 mg, VB_2 10 mg, VB_6 1 mg, VB_{12} 50 g, nicotinic acid 42.9 mg, pantothenic acid 21.6 mg, biotin 80 g, folic acid 5 mg, choline chloride 1,500 mg.
[2]Nutrient levels were all calculated values.

1.4 Feeding Management

The experiment was conducted at the Lukou Original Breed Pig Farm of Hunan Xinguang' an Agriculture and Livestock Co., Ltd., following strict biosecurity and management protocols. Sows were fed twice daily at 07:30 and 15:00 with ad libitum access to water. Pens were cleaned twice daily, and the surrounding areas were disinfected with spray every three days. Management and environmental conditions were consistent across all groups.

1.5 Sample Collection and Measurements

Feces: Defecation patterns of sows during late gestation were continuously monitored. Fecal characteristics were evaluated based on color, shape, and moisture content using the following criteria: 1) Color was described as black, brown, or yellow; 2) Shape and moisture content were classified as hard (low moisture), normal (formed, moderate moisture), soft (unformed but piled, high moisture), or watery (unformed, not piled, excessive moisture).

Backfat thickness: Backfat thickness was measured on day 110 of gestation and day 21 postpartum using a backfat and loin-eye ultrasound device (MyLab Touch VET). Backfat thickness loss was calculated as the difference between pre- and post-farrowing measurements.

Reproductive performance: Daily feed intake was recorded for each sow. Total piglets born, healthy piglets per litter, and farrowing duration (interval from first piglet to placenta expulsion) were recorded. Birth litter weight and litter weights at 7, 14, and 21 days of age were measured.

Milk yield: Milk yield was estimated based on the approximation that 1 kg of piglet weight gain requires 3 kg of sow milk. The calculation formula was:
Milk yield = (Litter weight at 21 days - Birth litter weight) × 3.

Milk composition: Colostrum (10 mL) was collected on the day of parturition, and milk (10 mL) was collected on day 10 of lactation. Conventional nutrient components (milk fat, milk protein, lactose, urea nitrogen [UN], defatted dry matter, total dry matter) were analyzed using a milk composition analyzer (MilkoScan™ FT+, FOSS, Denmark). Amino acid content was determined using an L-8800 automatic amino acid analyzer (Hitachi, Japan) according to established methods.

Plasma biochemical parameters: On day 21 postpartum, 10 mL of blood was collected from the anterior vena cava into heparinized tubes, gently mixed, allowed to stand at room temperature for 30 minutes, and then centrifuged to harvest plasma. Plasma concentrations of glutamic-pyruvic transaminase (GPT), glutamic-oxaloacetic transaminase (GOT), alkaline phosphatase (ALP), α-amylase (α-AMY), lactate dehydrogenase (LDH), total protein (TP), albumin (ALB), UN, glucose (GLU), triglyceride (TG), total cholesterol (CHO), high-density lipoprotein (HDL), and low-density lipoprotein (LDL) were measured using a 7060 automatic biochemical analyzer (Hitachi, Japan). All biochemical assay kits were purchased from Beijing Leadman Biochemistry Co., Ltd.

1.6 Data Processing and Analysis

Experimental data were initially processed using Excel 2010 and subsequently analyzed using SAS 9.1 (SAS Institute Inc.) via one-way ANOVA. Significant differences were further analyzed using Duncan' s multiple comparison test. Results are expressed as means ± standard error, with $P<0.05$ considered statistically significant.

2.1 Effects of Oligo-chitosan on Feces and Backfat Thickness of Sows

As shown in Table 2 , sows in the control group exhibited constipation during late gestation, whereas dietary oligo-chitosan supplementation improved fecal consistency by reducing hardness and increasing moisture content.

Table 2 Effects of oligo-chitosan on feces of sows

Items	Control group	Experimental group	Experimental group
Color			
Shape			
Moisture content			

Table 3 presents the backfat thickness measurements. No significant differences were observed among groups in backfat thickness on day 110 of gestation or day 21 postpartum ($P>0.05$). However, backfat thickness loss tended to be lower in experimental groups I and II compared with the control group ($P>0.05$).

Table 3 Effects of oligo-chitosan on backfat thickness of sows

Items	Control group	Experimental group	Experimental group	P-value
Day 110 of pregnancy (mm)	16.54±0.66	17.18±1.36	16.78±0.80	
Day 21 postpartum (mm)	15.42±0.62	16.16±1.22	15.95±0.76	
B[illegible]				

In the same row, values with the same or no letter superscripts indicate no significant difference (P>0.05), while different lowercase letter superscripts indicate significant difference (P<0.05). The same applies below.

2.2 Effects of Oligo-chitosan on Reproduction Performance of Sows

Table 4 summarizes the reproductive performance data. No significant differences were observed among groups in total piglets born per litter (P>0.05). However, the number of healthy piglets per litter was significantly higher in both experimental groups I and II compared with the control group (P<0.05), with experimental group I showing significantly more healthy piglets than group II (P<0.05). Farrowing duration was significantly shorter in both experimental groups compared with the control group (P<0.05). Additionally, ADFI during lactation was significantly higher in both experimental groups I and II relative to the control group (P<0.05). Birth litter weight was significantly increased in experimental group I (P<0.05), while total milk yield during lactation was significantly elevated in experimental group II (P<0.05).

Table 4 Effects of oligo-chitosan on reproduction performance of sows

Items	Control group	Experimental group	Experimental group	P-value
Total piglets born per litter	10.57±1.31	12.86±0.59	11.00±0.94	
Healthy piglets per litter	8.29±0.52^c	12.14±0.34^a	10.13±0.44^b	< 0.01
Farrowing duration (h)	4.07±0.17^a	3.50±0.21^b	3.35±0.15^b	< 0.01
ADFI of late pregnancy sows (kg)	2.27±0.03	2.35±0.04	2.38±0.04	
ADFI of lactation sows (kg)	3[illegible]	[illegible]	[illegible]	0.01
Birth litter weight (kg)	13.42±1.06^b	18.45±0.88^a	15.29±1.01^b	< 0.01
Litter weight at 7 days (kg)	26.54±0.35	30.81±1.35	27.65±1.65	
ADG from 1 to 7 days (g)	147.56±14[illegible]	[illegible]	[illegible]	0.01
Average daily milk yield (kg)	5.53±0.71	5.83±0.54	6.26±0.36	
Ratio of feed to milk	0.72±0.05	0.76[illegible]	[illegible]	[illegible]

2.3 Effects of Oligo-chitosan on Milk Composition of Sows

As presented in Table 5 , milk fat content in colostrum was significantly higher in both experimental groups I and II compared with the control group (P<0.05). Additionally, UN content in colostrum was significantly elevated in experimental group I (P<0.05). No significant differences were observed among groups in conventional nutrient components of regular milk (P>0.05).

Table 5 Effects of oligo-chitosan on conventional nutrient components of sow milk, %

Items	Control group	Experimental group	Experimental group	P-value
Colostrum				

Milk fat 4.11$±0.17^b|5.53±0.31^a|5.16±0.25^a| < 0.01||Milkprotein|17.56±0.54|17.47±0.43|16.65±0.52|||Lactose|4.14±0.23|3.86±0.19|4.04±0.13|||UN 0.01||Defatteddrymatter|25.49±0.69|25.16±0.75|24.48±0.55|||Totaldrymatter|32.68±0.71|34.02±0.5 *Milk* *|||||Milkfat|7.94±0.28|8.44±0.34|8.13±0.31|||Milkprotein|6.24±0.17|6.70±0.06|6.41±0.19|||Lactose

Table 6 shows the amino acid composition. No significant differences were observed among groups in amino acid content of colostrum (P>0.05). However, experimental group I exhibited significantly higher contents of arginine, total amino acids, and limiting amino acids in milk compared with both the control group and experimental group II (P<0.05). Additionally, threonine content in milk tended to be higher in experimental group I (0.05≤P<0.10).

Table 6 Effects of oligo-chitosan on amino acid contents of sow milk, %

Items	Control group	Experimental group	Experimental group	P-value
Colostrum				

Asp 1.09$±0.09|1.10[illegible]|Ser|0.90±0.09|0.86±0.08|0.81 *Milk* *|||||Asp|0.35±0.02|0.39±0.02|0.34±0.01|||Thr|0.18±0.02|0.22±0.01|0.19±0.01|||Ser|

[1]Limiting amino acids include lysine, methionine, and threonine.

2.4 Effects of Oligo-chitosan on Plasma Biochemical Parameters of Sows

Table 7 shows the plasma biochemical parameters. Plasma GPT activity was significantly lower in both experimental groups I and II compared with the control group (P<0.05). Experimental group II also exhibited a tendency for lower plasma ALP and LDH activities (0.05≤P<0.10). No significant differences were detected among groups in plasma TP, ALB, or UN concentrations (P>0.05). Although plasma concentrations of lipid metabolites (TG, CHO, HDL, LDL) were lower in both experimental groups compared with the control group, these differences were not statistically significant (P>0.05).

Table 7 Effects of oligo-chitosan on plasma biochemical parameters of sows

Items	Control group	Experimental group	Experimental group	P-value
GPT (U/L)	45.86±3.10^{a}	36.33±2.18^{b}	33.75±2.18^{b}	< 0.01
GOT (U/L)	25.57±1.73	26.50±2.62	21.25±1.87	
ALP (U/L)	81.86±3.31	74.33±3.89	66.75±5.12	[illegible]
α-AMY (U/L)	1,574.92±68.32	1,644.02±56.89	1,719.37±60.61	
LDH (U/L)	308.42±14.51	298.76±19.52	260.40±8.[illegible]	[illegible]

3.1 Effects of Dietary Oligo-chitosan on Reproduction Performance of Sows

Farrowing duration not only affects litter size but also influences piglet survival rates postpartum and sow longevity. Prolonged farrowing can lead to postpartum hemorrhage and infection, subsequently causing inflammation, extending the weaning-to-estrus interval, and increasing the sow' s infertility rate in the subsequent parity. For piglets, prolonged retention in the birth canal increases the risk of asphyxiation and death. Research indicates that large quantities of hard fecal masses in the sow' s intestine can compress the birth canal, impeding piglet passage. Additionally, pain associated with constipation promotes the secretion of opioid peptides, which inhibit oxytocin release and reduce uterine contractile strength. In this study, dietary oligo-chitosan supplementation significantly shortened farrowing duration by 14.00% and 17.69% in the 50 and 100 g/t groups, respectively, compared with the control group. This effect likely results from oligo-chitosan' s ability to improve gut microecological balance, thereby alleviating compression of the birth canal by hard fecal masses and facilitating rapid delivery. The results also confirm that oligo-chitosan supplementation improves constipation in late-gestation sows, possibly by inhibiting the proliferation of intestinal pathogenic bacteria and thereby enhancing gut microecological balance.

Feed intake is crucial for lactating sows. Low feed intake during lactation not only reduces milk yield and affects piglet growth and development but also leads to excessive body fat loss, prolonging the weaning-to-estrus interval. In this study, supplementation with 50 and 100 g/t oligo-chitosan significantly increased ADFI during lactation compared with the control group, indicating that oligo-chitosan enhances feed intake, which is highly beneficial for increasing milk yield and promoting piglet growth. The results also demonstrated that 50 g/t oligo-chitosan increased birth litter weight and litter weights at 7 and 14 days of age compared with the control group.

During lactation, sows mobilize body reserves to maintain milk production, but excessive mobilization can cause severe weight loss, negatively affecting piglet weight gain and extending the weaning-to-estrus interval while reducing conception rates. Although 100 g/t oligo-chitosan significantly increased total milk yield during lactation, it may have increased backfat thickness loss due to greater mobilization of body reserves. However, because oligo-chitosan supplementation increased ADFI during lactation, backfat thickness loss did not differ significantly from the control group.

3.2 Effects of Dietary Oligo-chitosan on Lactation Performance of Sows

Lactation performance is closely related to reproductive performance in animals. The conventional nutrient composition and milk yield of sow milk are intimately associated with piglet survival and growth, making them important considerations in sow diet formulation. This study demonstrates that oligo-chitosan supplementation increases total milk yield and average daily milk yield during lactation, likely reflecting the combined effects of inhibiting and clearing intestinal pathogenic bacteria while enhancing sow immunity. Lactose, milk fat, and milk protein are essential nutrients in sow milk, and their concentrations directly affect piglet performance. While lactose and milk protein content in sow milk typically remain stable despite dietary changes, milk fat in colostrum and milk is primarily utilized by neonatal piglets for body fat deposition. This study found that oligo-chitosan supplementation significantly increased milk fat content in colostrum, which benefits piglet body fat deposition and overall growth and development.

Research has shown that abundant amino acids in milk are used by piglets to synthesize body proteins, hormones, polyamines, purines, pyrimidines, and other biologically active molecules that promote growth and development. In this study, supplementation with 50 g/t oligo-chitosan significantly increased total amino acid and limiting amino acid concentrations in milk compared with the control group, which may be related to oligo-chitosan-mediated mechanisms of amino acid transport in mammary epithelial cells. Further research is warranted to elucidate the effects of oligo-chitosan on amino acid uptake by mammary glands.

3.3 Effects of Dietary Oligo-chitosan on Plasma Biochemical Parameters of Sows

Plasma biochemical parameters serve as important indicators of organ function and metabolic status in animals. Plasma ALP, GPT, and GOT activities are commonly used to assess liver health, while TP, ALB, and UN concentrations reflect protein metabolism and amino acid balance. The significantly lower plasma GPT activity in oligo-chitosan-supplemented groups is consistent with findings from studies on growing-finishing pigs. The tendency for lower plasma ALP and LDH activities in the 100 g/t oligo-chitosan group suggests that oligo-chitosan may enhance humoral immunity and improve liver health. This effect likely stems from oligo-chitosan' s antimicrobial properties and its ability to activate macrophages and T lymphocytes, thereby enhancing phagocytic and cytotoxic activity, helping the animal resist pathogenic infections and strengthening immune function to protect liver health. The absence of significant differences in plasma TP, ALB, and UN concentrations among groups indicates that oligo-chitosan does not significantly affect protein metabolism in pregnant sows.

Conclusion

Dietary oligo-chitosan supplementation promotes both reproduction and lactation performance in sows. Oligo-chitosan increases lactation feed intake, thereby enhancing milk yield and litter weight; reduces farrowing duration, consequently increasing the number of healthy piglets; and elevates colostrum milk fat content to promote piglet health and development. Additionally, oligo-chitosan improves constipation and reduces backfat thickness loss, demonstrating its effectiveness as a feed additive. Based on the comprehensive results of this study, the optimal supplementation level of oligo-chitosan in sow diets is 50 g/t.

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