Effects of Chitosan on Growth Performance, Slaughter Performance, Organ Indices, and Serum Biochemical Indices in 14- to 70-Day-Old Yangzhou Geese (Postprint)

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

Abstract

This experiment aimed to investigate the effects of dietary supplementation with different levels of chitosan on growth performance, slaughter performance, organ indices, and serum biochemical indices of Yangzhou geese aged 14–70 days, in order to determine the appropriate supplementation level of chitosan in goose diets. A total of 360 healthy 14-day-old Yangzhou ganders with similar body weight were selected and randomly divided into 5 groups, with 6 replicates per group and 12 geese per replicate. The control group was fed a basal diet, while the experimental groups were fed experimental diets supplemented with 250, 500, 1,000, and 2,000 mg/kg chitosan in the basal diet. The experimental period lasted 56 days. The results showed that, compared with the control group: 1) Dietary supplementation with 500 mg/kg chitosan significantly increased the body weight of geese at 42, 56, and 70 days of age, as well as the average daily feed intake and average daily gain during 14–70 days of age ($P<0.05$), and significantly decreased the feed conversion ratio during 14–70 days of age ($P<0.05$). 2) Dietary supplementation with 250, 500, 1,000, and 2,000 mg/kg chitosan significantly decreased the abdominal fat percentage of geese ($P<0.05$). 3) Dietary supplementation with 500 mg/kg chitosan significantly increased the heart index, liver index, spleen index, jejunum index, ileum index, and cecum index of geese ($P<0.05$). 4) Dietary supplementation with 500 mg/kg chitosan significantly increased serum globulin and glucose contents ($P<0.05$), and significantly decreased serum alkaline phosphatase activity ($P<0.05$); dietary supplementation with 250, 500, and 1,000 mg/kg chitosan significantly decreased serum triglyceride and total cholesterol contents ($P<0.05$). It can be concluded that dietary chitosan supplementation can improve the growth performance of Yangzhou geese and has certain effects on their slaughter performance, organ in-

dices, and serum biochemical indices. In production practice, supplementation of chitosan at 500 mg/kg in Yangzhou goose diets yields the best results.

Full Text

Effects of Chitosan on Growth Performance, Slaughter Performance, Viscera Indices and Serum Biochemical Parameters of Geese during 14 to 70 Days of Age

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Abstract

This experiment was conducted to investigate the effects of dietary supplementation with different levels of chitosan on growth performance, slaughter performance, viscera indices, and serum biochemical parameters of geese aged 14 to 70 days, and to determine the optimal supplemental level of chitosan in goose diets. A total of 360 healthy 14-day-old male Yangzhou geese with similar body weight were randomly allocated into 5 groups, each consisting of 6 replicates with 12 geese per replicate. The control group was fed a basal diet, while the experimental groups were fed the basal diet supplemented with 250, 500, 1,000, and 2,000 mg/kg chitosan, respectively. The trial lasted for 56 days. The results showed that, compared with the control group: (1) dietary supplementation with 500 mg/kg chitosan significantly increased body weight at 42, 56, and 70 days of age, average daily feed intake (ADFI), and average daily gain (ADG) during 14 to 70 days of age ($P<0.05$), while significantly decreasing the feed-to-gain ratio (F/G) during the same period ($P<0.05$); (2) dietary supplementation with 250, 500, 1,000, and 2,000 mg/kg chitosan significantly reduced the abdominal fat percentage ($P<0.05$); (3) dietary supplementation with 500 mg/kg chitosan significantly increased the heart index, liver index, spleen index, jejunum index, ileum index, and cecum index ($P<0.05$); and (4) dietary supplementation with 500 mg/kg chitosan significantly elevated serum globulin and glucose contents ($P<0.05$) while significantly decreasing serum alkaline phosphatase activity ($P<0.05$). Additionally, dietary supplementation with 250, 500, and 1,000 mg/kg chitosan significantly reduced serum triglyceride and total cholesterol contents ($P<0.05$). These findings indicate that dietary chitosan supplementation can improve the growth performance of Yangzhou geese and exert certain effects on slaughter performance, viscera indices, and serum biochemical parameters. In practical production, the optimal supplemental level of chitosan in Yangzhou goose diets is 500 mg/kg.

Keywords: chitosan; geese; growth performance; slaughter performance; viscera indices; serum biochemical parameters

Chitosan, as a novel green feed additive, can effectively reduce antinutritional factors in feed. It not only promotes nutrient digestion and utilization but also exhibits antioxidant, antibacterial, and immune-enhancing properties while stimulating metabolism and protein synthesis, thereby promoting animal growth and improving growth performance [1-2]. Tarasewicz et al. [3] conducted a comparative study on 5-week-old quail, where the control group received a basal diet and the experimental group received the basal diet supplemented with 5.2 mL chitosan per 1.2 kg of feed. The results demonstrated that the experimental group achieved 5.0% higher weight gain and 6.7% improved feed utilization, along with increased egg production, feed conversion rate, survival rate, and hatchability. Previous research suggests that chitosan can alleviate stress, promote gastrointestinal motility, enhance pepsin activity, improve dietary protein digestibility, and increase intestinal microvillus height and density, thereby expanding the intestinal absorption area and facilitating nutrient absorption to promote growth. Wang et al. [4] found that adding 200 mg/kg chitosan to piglet diets significantly reduced mortality and markedly increased average daily gain. However, research on chitosan supplementation in geese remains scarce. Yangzhou geese are medium-sized breeds characterized by rapid early growth, coarse feed tolerance, and strong adaptability. This study aimed to investigate the effects of different dietary chitosan levels on growth performance, slaughter performance, viscera indices, and serum biochemical parameters of Yangzhou geese, thereby exploring the optimal supplemental level of chitosan in their diets to provide theoretical guidance for the scientific application of chitosan in meat goose production.

1.1 Experimental Materials

The chitosan used in this experiment was purchased from Jinan Haidebei Marine Biological Engineering Co., Ltd. The product appeared off-white, non-toxic, tasteless, semi-transparent, and powdery, with a deacetylation degree >95.38%, particle size of 0.178 mm, viscosity of 50 mPa · s, and moisture content <7%.

Experimental animals were 14-day-old male Yangzhou geese purchased from Yangzhou Goose Breeding Farm in Yangzhou City.

1.2 Experimental Design and Diets

A total of 360 healthy 14-day-old male Yangzhou geese from the same hatch, with similar body weight, were individually tagged and randomly allocated into 5 groups using a single-factor experimental design. Each group comprised 6 replicates with 12 geese per replicate. The control group (Group I) received the basal diet, while the experimental groups (Groups II, III, IV, and V) received the basal diet supplemented with 250, 500, 1,000, and 2,000 mg/kg chitosan, respectively. The trial period spanned from 14 to 70 days of age, lasting 56 days. Throughout the rearing period, geese had ad libitum access to feed and water under natural lighting conditions. Routine management practices were followed, maintaining clean housing and good ventilation. Daily observations and records of flock conditions were maintained.

The basal diets were formulated primarily based on NRC (1994) and relevant research findings from our laboratory [5-6]. Corn and soybean meal served as the basal ingredients. Prior to diet formulation, the metabolizable energy values and contents of crude protein, crude fiber, and other nutrients of all raw materials were determined. The composition and nutrient levels of the basal diets are presented in Table 1 and Table 2 .

1.3 Measurement Indicators and Methods

1.3.1 Growth Performance Body weight was individually measured at 14, 28, 42, 56, and 70 days of age after a 6-hour fasting period. Daily feed intake and weight gain were recorded for each group to calculate average daily feed intake (ADFI), average daily gain (ADG), and feed-to-gain ratio (F/G).

1.3.2 Slaughter Performance At the end of the feeding trial (70 days of age), after 6 hours of fasting, geese were weighed and slaughtered by exsanguination. Carcass weight, semi-eviscerated weight, fully eviscerated weight, breast muscle weight, leg muscle weight, and abdominal fat weight were measured to calculate dressing percentage, semi-eviscerated yield, eviscerated yield, breast muscle percentage, leg muscle percentage, and abdominal fat percentage. Measurements were conducted according to NY/T 823—2004 "Poultry Production Performance Terminology and Measurement Statistics Methods" [7].

1.3.3 Viscera Indices After slaughter and exsanguination, the heart, liver (gallbladder removed), gizzard (contents removed), proventriculus, spleen, bursa of Fabricius, and various intestinal segments (with adipose tissue and intestinal contents removed) were weighed to calculate viscera indices using the following formula: Viscera index = [organ weight (g) / pre-slaughter live weight (g)] × 100.

1.3.4 Serum Biochemical Parameters Serum total protein (TP), globulin (GLB), glucose (GLU), uric acid (UA), urea nitrogen (UN), triglyceride (TG), and total cholesterol (TC) contents, as well as aspartate aminotransferase (AST) and alkaline phosphatase (ALP) activities, were determined using a Unicel Dxc 800 Synchron automatic biochemical analysis system (Beckman Coulter, USA).

1.4 Data Analysis

Experimental data were organized using Excel software. One-way ANOVA was performed using the one-way ANOVA module of SPSS 17.0 statistical software. Duncan' s multiple comparison test was used for significance testing. Results were expressed as mean ± standard deviation, with P<0.05 as the criterion for significant difference.

2.1 Effects of Different Chitosan Levels on Growth Performance of Geese Aged 14 to 70 Days

As shown in Table 3 , dietary supplementation with different chitosan levels affected the body weight of geese at 42, 56, and 70 days of age. At 42 days, Group III exhibited significantly higher body weight than Groups I, II, IV, and V (P<0.05), while Groups II and IV showed significantly higher body weight than Groups I and V. At 56 days, Groups II and III had significantly higher body weight than Groups I, IV, and V (P<0.05), and Groups I and IV had significantly higher body weight than Group V (P<0.05). At 70 days, Group III demonstrated significantly higher body weight than Groups I, II, IV, and V (P<0.05), and Group II had higher body weight than Groups I, IV, and V (P<0.05). No significant differences in body weight were observed among groups at 14 and 28 days of age (P>0.05). These results indicate that dietary supplementation with 250–1,000 mg/kg chitosan promoted the growth and development of goslings, with 500 mg/kg showing the most pronounced effect, whereas supplementation with 2,000 mg/kg chitosan inhibited growth.

Table 4 reveals that dietary supplementation with different chitosan levels influenced ADFI, ADG, and F/G in geese. During 14–28 days of age, Group III exhibited significantly higher ADFI than Groups I, II, and V (P<0.05). During 29–70 days of age, Group III showed significantly higher ADFI than Groups I and V (P<0.05), significantly higher ADG than Groups I, II, IV, and V (P<0.05), and significantly lower F/G than Groups I, IV, and V (P<0.05), while Group II had significantly higher ADG than Groups I, IV, and V (P<0.05). Throughout the entire 14–70 day period, Group III demonstrated significantly higher ADFI and ADG than Groups I, II, IV, and V (P<0.05), along with significantly lower F/G than Groups I, IV, and V (P<0.05).

Overall, chitosan supplementation at different levels affected the growth performance of goslings during 14–70 days of age. Within the range of 250–500 mg/kg, ADFI and ADG showed an upward trend while F/G gradually decreased. Conversely, within the range of 1,000–2,000 mg/kg, ADFI and ADG exhibited a downward trend while F/G gradually increased.

2.2 Effects of Different Chitosan Levels on Slaughter Performance of Geese at 70 Days of Age

As presented in Table 5 , Group I showed significantly higher abdominal fat percentage than Groups II, III, IV, and V (P<0.05). No significant differences were observed among groups in dressing percentage, semi-eviscerated yield, eviscerated yield, breast muscle percentage, or leg muscle percentage (P>0.05). From the perspective of slaughter performance, dietary chitosan supplementation reduced the abdominal fat percentage of 70-day-old geese.

2.3 Effects of Different Chitosan Levels on Viscera Indices of Geese at 70 Days of Age

Table 6 demonstrates that dietary supplementation with different chitosan levels exerted varying effects on visceral organs. Groups II, III, and IV exhibited significantly higher heart indices than Groups I and V ($P<0.05$). Group III showed significantly higher liver index than Groups I, II, IV, and V ($P<0.05$). Groups II, III, and IV had significantly higher spleen indices than Groups I and V ($P<0.05$). Group III demonstrated significantly higher gizzard index than Group V ($P<0.05$). Group III exhibited significantly higher jejunum index than Groups I, IV, and V ($P<0.05$). Additionally, Group III showed significantly higher ileum and cecum indices than Group I ($P<0.05$). Overall, chitosan supplementation at 500 mg/kg produced the most significant effects on visceral organ development in goslings.

2.4 Effects of Different Chitosan Levels on Serum Biochemical Parameters of Geese at 70 Days of Age

As shown in Table 7 , dietary supplementation with different chitosan levels influenced serum biochemical parameters. Groups II and III exhibited significantly higher serum GLB content than Group I ($P<0.05$). Groups II, III, IV, and V showed significantly higher serum GLU content than Group I ($P<0.05$). Group I had significantly higher serum TG content than Groups II, III, IV, and V ($P<0.05$). Group I demonstrated significantly higher serum TC content than Groups II, III, and IV ($P<0.05$). Groups I, II, and III showed significantly lower serum UA content than Groups IV and V ($P<0.05$). Groups I, II, III, and IV exhibited significantly lower serum AST activity than Group V ($P<0.05$). Groups II and III demonstrated significantly lower serum ALP activity than Groups I and IV ($P<0.05$).

Compared with the control group, appropriate chitosan supplementation increased serum GLB and GLU contents while decreasing serum TC and TG contents, with the 500 mg/kg supplementation showing the most significant effects. In contrast, supplementation with 1,000 and 2,000 mg/kg chitosan increased serum UA content and AST and ALP activities compared with 250 and 500 mg/kg supplementation.

3.1 Effects of Different Chitosan Levels on Growth Performance of Geese Aged 14 to 70 Days

The mechanism by which chitosan promotes animal growth remains unclear, and systematic research reports are lacking. Based on previous studies, the growth-promoting mechanisms of chitosan are primarily manifested in several aspects: the complex spatial structure of chitosan contains highly active functional groups that exhibit antibiotic-like properties, promoting the growth of beneficial intestinal bacteria while inhibiting other microorganisms and demonstrating enhanced bactericidal activity [8-9]; it effectively enhances macrophage phagocytic function and hydrolase activity, stimulates macrophages to produce lymphokines, and strengthens immune function [10-11]; it alleviates stress responses; it promotes gastrointestinal motility, enhances pepsin activity, improves dietary protein digestibility, and increases intestinal microvillus height and density, thereby expanding the intestinal absorption area and facilitating nutrient absorption to achieve growth promotion. Liu et al. [12] found that dietary supplementation with 50, 100, and 150 mg/kg chitosan significantly improved ADG in broiler chickens, with 100 mg/kg showing the best results. Zhang et al. [13] reported that feeding broiler chickens with 200 g/t chitosan promoted growth and feed conversion, with the chitosan-supplemented group showing significantly higher ADG than the control group. Zhu et al. [14] supplemented broiler diets with low-dose chitosan (0, 200, 600, and 1,000 mg/kg) during 1–2 weeks of age, and the results indicated that growth performance improved with increasing chitosan levels within this range. Wu et al. [15] obtained similar results in 1–3-week-old broilers, finding that 0.2% chitosan significantly improved growth rate and reduced F/G, whereas 0.5% chitosan exhibited inhibitory effects. Zhang et al. [16] discovered that dietary supplementation with 0.01%–0.05% chitosan significantly affected ADG, ADFI, and F/G in piglets, with the 0.05% chitosan group showing significantly higher ADG and ADFI than the control and other experimental groups. Xiao et al. [17] found that dietary supplementation with 200, 300, and 400 mg/kg chitosan significantly increased ADFI and reduced F/G in piglets, with the effects on growth performance gradually strengthening as chitosan levels increased within this range.

The results of this study are somewhat consistent with the aforementioned findings. Dietary supplementation with 500 mg/kg chitosan significantly improved ADG and ADFI while reducing F/G in geese. However, supplementation with 2,000 mg/kg chitosan significantly decreased ADFI and ADG and increased F/G. The reason may be that chitosan, as the only alkaline polysaccharide, exhibits a dose-dependent relationship in its effects on animal performance. At lower doses (250 and 500 mg/kg), chitosan functions similarly to fiber in the gastrointestinal tract, influencing nutrient digestion, metabolism, and the digestive system, thereby promoting growth. At higher doses (2,000 mg/kg), the polysaccharide can bind substantial amounts of water, increasing digesta viscosity and impairing nutrient digestion and absorption, thus failing to promote growth or even inhibiting it, consequently reducing growth performance in geese.

3.2 Effects of Different Chitosan Levels on Slaughter Performance of Geese at 70 Days of Age

Chitosan possesses lipid-lowering properties and is not soluble in gastric acid. It forms chitosan-lipid complexes with dietary fat, which create colloids in the small intestine that adsorb fat and excrete it with feces, thereby reducing fat absorption [18]. Xia et al. [19] found that dietary supplementation with 100, 200, 300, and 400 g/t chitosan had no significant effect on the slaughter performance of Tianshan snow geese. Huang et al. [20] reported that dietary supplementation with 0.2% chitosan had no significant influence on dressing percentage, semi-eviscerated yield, eviscerated yield, breast muscle percentage, or leg muscle percentage in Guifei chickens. The present study similarly demonstrated that dietary supplementation with 250, 500, 1,000, and 2,000 mg/kg chitosan had no significant effects on dressing percentage, semi-eviscerated yield, eviscerated yield, breast muscle percentage, or leg muscle percentage in geese, consistent with the aforementioned conclusions.

Cahaner et al. [21] found that abdominal fat exhibited moderate to high phenotypic and genetic correlations with carcass traits, and the amount of abdominal fat deposition could reflect body dynamics to some extent. Fat is digested and absorbed after emulsification by bile acids, and chitosan with positively charged alkaline amino groups can complex with bile acids, preventing fat absorption and promoting its excretion from the body, thereby reducing fat deposition [22]. Xia et al. [19] discovered that dietary supplementation with 100, 200, 300, and 400 g/t chitosan reduced carcass fat content to varying degrees in Tianshan snow geese, with 300 g/t showing the best effect. Ke et al. [23] found that chitosan reduced abdominal fat percentage and decreased body fat deposition in meat quail. The current study demonstrated that dietary supplementation with different chitosan levels (250, 500, 1,000, and 2,000 mg/kg) significantly reduced abdominal fat percentage, consistent with the above findings.

3.3 Effects of Different Chitosan Levels on Viscera Indices of Geese at 70 Days of Age

The growth and development of visceral organs ensure effective nutrient deposition in muscles, bones, and other organs, directly affecting nutrient digestion and absorption in geese. Viscera indices, defined as the ratio of organ weight to live body weight, are commonly used to represent visceral organ development and can effectively reflect the growth stage and physiological functional status of animals, primarily influenced by breed and nutritional factors [24].

This study found that dietary supplementation with appropriate chitosan levels increased viscera indices in geese, with heart, liver, spleen, and gizzard indices decreasing to varying degrees as dietary chitosan levels increased. These results indicate that chitosan levels within the range of 250–1,000 mg/kg can promote visceral organ development and increase the ratio of visceral organ weight to body weight. During the rearing period, it was observed that geese in the 500 mg/kg supplementation group produced less fecal excretion with lower viscosity compared with other groups. This may be because chitosan increased digesta passage rate and reduced intestinal digesta viscosity, thereby enhancing nutrient absorption rate in the intestine. This process may influence the types and quantities of intestinal microorganisms, which in turn affect intestinal growth and development, though the specific mechanisms require further investigation.

3.4 Effects of Different Chitosan Levels on Serum Biochemical Parameters of Geese at 70 Days of Age

Serum TC and TG are two important indicators reflecting normal lipid metabolism function in animals. In acidic environments, chitosan releases ammonium ions (NH3+), and the positively charged chitosan binds with negatively charged bile acids for excretion, leading to gallbladder emptying. Since the gallbladder must maintain a certain bile acid reserve, plasma or hepatic cholesterol is converted into bile acids, reducing bile acid reabsorption and consequently decreasing plasma or hepatic cholesterol concentrations. When chitosan binds with bile acids and is excreted, fat cannot be emulsified, affecting its intestinal absorption and thus reducing serum TG content [25]. The present study demonstrated that dietary supplementation with appropriate chitosan levels (250, 500, 1,000, and 2,000 mg/kg) significantly reduced serum TG and TC contents.

Serum TP and GLB contents in animals reflect, to some extent, protein absorption and catabolism status [26] and can represent the degree of protein digestion and utilization as well as the immune status of the organism [27-28]. Serum GLU is the sole energy source for animal metabolism (including adipose tissue, central nervous system, and muscles), a prerequisite for synthesizing the reducing coenzyme (NADPH) required for fat metabolism and for synthesizing lactose and milk fat, and an indispensable nutrient in animals [29]. Shi et al. [30] found that dietary supplementation with 100 mg/kg chitosan significantly increased serum TP content while significantly reducing serum UA content in broiler chickens. The current study showed that chitosan significantly increased serum TP content, indicating its promotional effect on protein deposition and synthesis, consistent with the aforementioned findings. Serum UN and UA contents are negatively correlated with protein metabolism and utilization efficiency in poultry, and their levels can reflect the degree of protein catabolism and kidney functional health. In this study, the 500 mg/kg chitosan group significantly reduced serum UA content, suggesting that appropriate chitosan supplementation can improve protein metabolism and amino acid balance, enhance nutrient absorption, and increase feed utilization efficiency in geese, which aligns with the observed increase in serum TP and GLB contents.

AST and ALP are primarily present in hepatocytes, and their activity changes are important indicators of liver and cardiac cell damage. Under normal conditions, serum AST and ALP activities remain relatively stable; however, when tissues undergo pathological changes or necrosis, intracellular enzymes are released into the bloodstream, leading to elevated serum AST and ALP activities [31-32]. The present study showed that, compared with the control group, chitosan-supplemented groups exhibited a decreasing trend in serum ALP activity, while the 2,000 mg/kg chitosan group displayed higher serum AST activity than other groups. These results suggest that chitosan supplementation at 250–1,000 mg/kg causes no damage to the liver or heart in geese, providing a basis for its application in production.

Conclusion

Dietary supplementation with 500 mg/kg chitosan significantly affected growth performance in geese, increasing body weight at 42, 56, and 70 days of age and improving feed utilization efficiency and economic benefits.

Dietary supplementation with 500 mg/kg chitosan significantly affected viscera indices in 70-day-old geese, while appropriate chitosan supplementation (250, 500, 1,000, and 2,000 mg/kg) significantly reduced abdominal fat percentage in 70-day-old geese.

Dietary supplementation with 500 mg/kg chitosan significantly increased serum GLB content, while appropriate chitosan supplementation (250, 500, 1,000, and 2,000 mg/kg) significantly increased serum GLU content and significantly reduced serum TG and TC contents and ALP activity.

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