Effects of Polygonatum Polysaccharide on Production Performance, Egg Quality, Hatching Performance, and Serum Antioxidant Indices in Breeding Quail (Postprint)

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Date: 2018-12-24T00:00:00+00:00

Abstract

This experiment was conducted to investigate the effects of Polygonatum sibiricum polysaccharide (PSP) on production performance, egg quality, hatching performance, and serum antioxidant indices of breeding quails. A total of 4,000 laying quails and 500 male quails were randomly assigned to 5 groups: a control group fed a basal diet, and experimental groups fed basal diets supplemented with 0.4% Astragalus polysaccharide (APS), and 0.1%, 0.4%, and 0.8% PSP, respectively. Each group consisted of 4 replicates, with each replicate containing 200 laying quails and 25 male quails. The preliminary period lasted 15 days, followed by a 30-day formal experimental period. The results showed: 1) The laying rate and average egg weight in the 0.4% PSP and 0.4% APS groups were significantly higher than those in the control and 0.1% PSP groups ($P<0.05$), while the average daily feed intake and feed-to-egg ratio in the 0.4% PSP, 0.8% PSP, and 0.4% APS groups were significantly lower than those in the control group ($P<0.05$). 2) Yolk color in all experimental groups was significantly higher than that in the control group ($P<0.05$), and Haugh units in the 0.4% PSP, 0.8% PSP, and 0.4% APS groups were significantly higher than those in the 0.1% PSP and control groups ($P<0.05$). 3) The fertilization rate, fertilized egg hatchability, and set egg hatchability in the 0.4% PSP, 0.8% PSP, and 0.4% APS groups were all significantly greater than those in the control group ($P<0.05$). 4) Serum total superoxide dismutase and glutathione peroxidase activities, as well as total antioxidant capacity, in the 0.4% PSP, 0.8% PSP, and 0.4% APS groups were significantly higher than those in the control group ($P<0.05$), whereas serum malondialdehyde content was significantly lower than that in the control and 0.1% PSP groups ($P<0.05$). These results suggest that dietary supplementation with 0.4% and 0.8% PSP can improve

production performance, increase yolk color and Haugh units, enhance hatching performance, and improve serum antioxidant capacity in breeding quails, with 0.4% PSP demonstrating the optimal effect.

Full Text

Effects of Polygonatum Polysaccharide on Performance, Egg Quality, Hatching Performance and Serum Antioxidant Indexes of Breeding Quails

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Abstract

This study investigated the effects of Polygonatum polysaccharide on the performance, egg quality, hatching performance, and serum antioxidant indexes of breeding quails. A total of 4,000 laying quails and 500 male quails were randomly divided into five groups: a control group fed a basal diet, and four experimental groups fed the basal diet supplemented with 0.4% Astragalus polysaccharide, or 0.1%, 0.4%, and 0.8% Polygonatum polysaccharide, respectively. Each group comprised four replicates, with each replicate containing 200 laying quails and 25 male quails. The pre-experimental period lasted 15 days, followed by a 30-day formal experimental period. The results showed: (1) The laying rate and average egg weight of the 0.4% Polygonatum polysaccharide group and 0.4% Astragalus polysaccharide group were significantly higher than those of the control group and 0.1% Polygonatum polysaccharide group ($P<0.05$), while the average daily feed intake and feed-to-egg ratio of the 0.4% Polygonatum polysaccharide, 0.8% Polygonatum polysaccharide, and 0.4% Astragalus polysaccharide groups were significantly lower than those of the control group ($P<0.05$). (2) Yolk color in all experimental groups was significantly higher than in the control group ($P<0.05$), and Haugh unit in the 0.4% Polygonatum polysaccharide, 0.8% Polygonatum polysaccharide, and 0.4% Astragalus polysaccharide groups was significantly higher than in the 0.1% Polygonatum polysaccharide and control groups ($P<0.05$). (3) The fertilization rate, hatching rate of fertilized eggs, and hatching rate of total eggs set in the 0.4% Polygonatum polysaccharide, 0.8% Polygonatum polysaccharide, and 0.4% Astragalus polysaccharide groups were all significantly higher than those of the control group ($P<0.05$). (4) Serum total superoxide dismutase (T-SOD) and glutathione peroxidase (GSH-Px) activities, as well as total antioxidant capacity (T-AOC), in the 0.4% Polygonatum polysaccharide, 0.8% Polygonatum polysaccharide, and 0.4% Astragalus polysaccharide groups were significantly higher than those of the control group ($P<0.05$), while serum malondialdehyde (MDA) content was significantly lower than that of the control group and 0.1% Polygonatum polysaccharide group (P<0.05). These results indicate that dietary supplementation with 0.4% and 0.8% Polygonatum polysaccharide can improve the performance of breeding quails, increase yolk color and Haugh unit, enhance hatching performance, and improve serum antioxidant function, with the 0.4% supplementation level showing the best effects.

Keywords: breeding quail; Polygonatum polysaccharide; performance; egg quality; hatching performance; serum antioxidant index

Introduction

In the quail breeding industry, the quality of breeding quails is crucial, and developing green feed additives without toxic side effects can optimize quail breed quality, improve the performance, egg quality, and hatching performance of breeding quails, and facilitate breed propagation. Polygonatum is a commonly used tonic medicine first recorded in the *Mingyi Bielu* [1], and polysaccharides are the most abundant components in Polygonatum plants [2]. Polysaccharides exhibit multiple biological activities without obvious toxic side effects [3], making them a research hotspot in food science, natural medicine, biochemistry, and life sciences. Previous studies have shown that dietary supplementation with 100 mg/kg Astragalus polysaccharide can significantly reduce the feed-to-egg ratio in laying hens, increase yolk color, and show increasing trends in laying rate, Haugh unit, and shell thickness [4]. Atractylodes polysaccharide can improve the average daily gain, average daily feed intake (ADFI), and feed utilization in quails [5]. Both alfalfa polysaccharide and Astragalus polysaccharide exhibit antioxidant effects in broiler chickens by scavenging DPPH, hydroxyl radicals, and superoxide anion radicals [6], with similar activities reported for Angelica polysaccharide and Epimedium polysaccharide [7-8]. Laminarin can lower blood lipids in experimental hyperlipidemic quails and inhibit atherosclerosis formation [9]. Gentian polysaccharide can enhance thymus and spleen indices and promote immune organ development in poultry [10]. Polygonatum polysaccharide exerts immunomodulatory effects on chicks by improving serum antioxidant function, increasing serum immunoglobulin content, and enhancing the immune capacity of the thymus, bursa of Fabricius, and spleen to maintain immune homeostasis [11]. Both Moringa polysaccharide and Pueraria flower polysaccharide can improve humoral immune function in poultry, thereby increasing disease resistance and performance [12]. However, most domestic and international research on Polygonatum polysaccharide has focused on developing immune enhancers and anti-inflammatory drugs for livestock and poultry, with limited understanding of its effects on breeding poultry. Therefore, this study supplemented Polygonatum polysaccharide in the diet of breeding quails to investigate its effects on performance, egg quality, hatching performance, and serum antioxidant indexes, providing a theoretical basis for its promotion and application.

1. Materials and Methods

1.1 Reagents and Materials Yellow-feather breeding quails were purchased from Meishan Jiaye Quail Breeding Professional Cooperative. Astragalus polysaccharide (effective content 80%, batch number 20160222) was purchased from Beijing Shengtaier Biological Technology Co., Ltd. Polygonatum polysaccharide (effective content 86%, batch number 20160321) was purchased from Shaanxi Sinuote Biological Technology Co., Ltd.

1.2 Experimental Design A total of 4,000 80-day-old yellow-feather laying quails and 500 male quails (configured at an 8:1 ratio) were randomly divided into five groups, with four replicates per group. Each replicate contained 200 laying quails and 25 male quails raised in online cages. The control group was fed a basal diet, the 0.4% Astragalus polysaccharide group was fed the basal diet supplemented with 0.4% Astragalus polysaccharide (added as pure product), and the remaining three groups were fed the basal diet supplemented with 0.1%, 0.4%, and 0.8% Polygonatum polysaccharide (added as pure product), respectively. The composition and nutrient levels of the basal diet are shown in Table 1 . The pre-experimental period lasted 15 days, and the formal experimental period lasted 30 days. On the final day of the formal period, 16 quail eggs were randomly collected from each group (four eggs per replicate).

1.3 Performance Measurement During the formal experimental period, the health status of breeding quails was observed daily, and feed intake, mortality, egg production, egg weight, broken eggs, and soft-shell eggs were accurately recorded for each replicate. Mortality rate, average daily egg production, laying rate, feed-to-egg ratio, and broken/soft-shell egg rate were calculated using the following formulas: Laying rate (%) = (total eggs laid / (number of quails × formal experimental days)) × 100; Feed-to-egg ratio = total feed intake / total egg weight; Broken/soft-shell egg rate (%) = (number of broken/soft-shell eggs / total eggs laid) × 100; Mortality rate (%) = (number of dead quails at the end of formal period / number of quails housed) × 100.

1.4 Egg Quality Measurement Egg weight was measured using an analytical balance, while egg shape index and yolk index (yolk height/yolk diameter) were measured using vernier calipers. Eggshell thickness, yolk color, albumen height, and Haugh unit were measured using eggshell thickness gauge and egg quality analyzer from Orka Company.

1.5 Hatching Performance Measurement Quail eggs were incubated in three batches (eggs were selected for incubation every 10 days). The number of eggs set, fertilized eggs, hatched chicks, and healthy chicks were recorded for each group and replicate. Fertilization rate, healthy chick rate, hatching rate of total eggs set, and hatching rate of fertilized eggs were calculated as follows: Fertilization rate (%) = (number of fertilized eggs / number of eggs set) × 100; Hatching rate of fertilized eggs (%) = (number of hatched chicks / number of fertilized eggs set) × 100; Hatching rate of total eggs set (%) = (number of hatched chicks / number of eggs set) × 100; Healthy chick rate (%) = (number of healthy chicks / number of hatched chicks) × 100. The incubation conditions in this experiment were consistent with local production practices: constant temperature of 37.8°C; humidity of 60% on days 1-6, 55% on days 7-15, and 65% on days 16-17; egg turning every 2 hours at a 90° angle; and regular ventilation.

1.6 Serum Antioxidant Index Detection At the end of the formal experimental period, four laying quails were randomly selected from each replicate (16 per group) for blood collection from the jugular vein. Blood samples were placed at an angle until serum separated, then centrifuged at 3,000 r/min for 15 minutes to prepare serum, which was stored at -20°C for later analysis. The measured indicators included total superoxide dismutase (T-SOD) activity, total antioxidant capacity (T-AOC), glutathione peroxidase (GSH-Px) activity, and malondialdehyde (MDA) content. All test kits were purchased from Nanjing Jiancheng Bioengineering Institute.

1.7 Statistical Analysis Experimental data were expressed as "mean ± standard deviation (SD)" and analyzed using the ANOVA procedure in SPSS 18.0 software. Duncan' s multiple comparison method was used for inter-group comparisons, with $P<0.05$ considered statistically significant.

2. Results

2.1 Effects of Polygonatum Polysaccharide on Performance of Breeding Quails As shown in Table 2 , ADFI in all experimental groups showed a decreasing trend, with significant differences observed between all groups except the 0.1% Polygonatum polysaccharide group and the control group ($P<0.05$). The laying rate of the 0.4% Polygonatum polysaccharide group and 0.4% Astragalus polysaccharide group was significantly higher than that of the control group and 0.1% Polygonatum polysaccharide group ($P<0.05$). Average egg weight in the 0.4% Polygonatum polysaccharide group and 0.4% Astragalus polysaccharide group was significantly higher than in the control group and 0.1% Polygonatum polysaccharide group ($P<0.05$). The feed-to-egg ratio in the 0.4% Polygonatum polysaccharide, 0.8% Polygonatum polysaccharide, and 0.4% Astragalus polysaccharide groups was significantly lower than in the control group ($P<0.05$).

2.2 Effects of Polygonatum Polysaccharide on Egg Quality of Breeding Quails As shown in Table 3 , no significant differences were observed among groups in egg weight, egg shape index, eggshell thickness, or yolk index ($P>0.05$). However, yolk color in all experimental groups was significantly higher than in the control group ($P<0.05$), with the 0.4% Polygonatum polysaccharide, 0.8% Polygonatum polysaccharide, and 0.4% Astragalus polysaccharide groups showing significantly higher values than the 0.1% Polygonatum polysaccharide group ($P<0.05$). Haugh unit in the 0.4% Polygonatum polysaccharide, 0.8% Polygonatum polysaccharide, and 0.4% Astragalus polysaccharide groups was significantly higher than in the 0.1% Polygonatum polysaccharide and control groups ($P<0.05$).

2.3 Effects of Polygonatum Polysaccharide on Hatching Performance of Breeding Quails As shown in Table 4 , no significant differences were observed among groups in birth weight ($P>0.05$). The fertilization rate in the 0.4% Polygonatum polysaccharide, 0.4% Astragalus polysaccharide, and 0.8% Polygonatum polysaccharide groups was significantly higher than in the 0.1% Polygonatum polysaccharide and control groups ($P<0.05$). The hatching rate of fertilized eggs and hatching rate of total eggs set in the 0.4% Polygonatum polysaccharide, 0.8% Polygonatum polysaccharide, and 0.4% Astragalus polysaccharide groups were significantly higher than in the control group ($P<0.05$). All experimental groups showed significantly higher healthy chick rates than the control group ($P<0.05$), with the 0.4% Polygonatum polysaccharide, 0.8% Polygonatum polysaccharide, and 0.4% Astragalus polysaccharide groups showing significantly higher rates than the 0.1% Polygonatum polysaccharide group ($P<0.05$).

2.4 Effects of Polygonatum Polysaccharide on Serum Antioxidant Indexes of Breeding Quails As shown in Table 5 , serum T-SOD activity and T-AOC in the 0.4% Astragalus polysaccharide, 0.4% Polygonatum polysaccharide, and 0.8% Polygonatum polysaccharide groups were significantly higher than in the control group and 0.1% Polygonatum polysaccharide group ($P<0.05$). Serum GSH-Px activity in these three groups was also significantly higher than in the control group ($P<0.05$). Serum MDA content in the 0.4% Astragalus polysaccharide, 0.4% Polygonatum polysaccharide, and 0.8% Polygonatum polysaccharide groups was significantly lower than in the control group and 0.1% Polygonatum polysaccharide group ($P<0.05$).

3. Discussion

3.1 Effects of Polygonatum Polysaccharide on Performance of Breeding Quails Although no studies have reported the effects of Polygonatum polysaccharide on poultry performance, polysaccharides have shown promising results in enhancing production performance. Liu et al. [13] demonstrated that traditional Chinese medicine formulations with blood- and qi-regulating effects can improve oxygen transport capacity in blood, thereby enhancing laying hen performance. Wang et al. [14] found that Astragalus polysaccharide can improve the immune system of broiler chickens and enhance chick performance, with 0.4% Polygonatum polysaccharide showing the best effects. Zhao and Li [15] reported that dietary Astragalus polysaccharide can increase ADFI and reduce feed-to-weight ratio, thereby improving broiler performance, which is consistent with our findings. This study showed that compared with the control group, both 0.4% and 0.8% Polygonatum polysaccharide groups exhibited improved performance, possibly because Polygonatum polysaccharide can regulate qi and blood, enhance disease resistance, increase feed utilization, and improve production potential, resulting in increased egg weight and reduced broken and soft-shell eggs. Egg production is a complex physiological process regulated by the neuroendocrine system in poultry [16], and quails experience continuous heavy ovulation during peak laying periods [17], leading to accumulated oxidative damage and significantly decreased performance [18]. Chen et al. [19] demonstrated that dandelion polysaccharide can increase laying hen performance. Xin et al. [20] and Wang et al. [21] both showed that dietary alfalfa polysaccharide can significantly increase laying rate. Guan et al. [16] reported that Astragalus polysaccharide can influence the neuroendocrine system by regulating hormone secretion and metabolism, thereby improving laying hen performance. The increased laying rate observed in this study with appropriate Polygonatum polysaccharide supplementation may be related to polysaccharide-mediated endocrine system regulation, though the specific mechanism requires further investigation.

3.2 Effects of Polygonatum Polysaccharide on Egg Quality of Breeding Quails Yolk color represents the nutritional value of eggs, and its intensity depends on the amount and type of carotenoids consumed from the diet. Haugh unit is the primary indicator for assessing quail egg freshness; higher Haugh units indicate fresher eggs with thicker protein and better quality. Wang et al. [22] reported that dietary Astragalus polysaccharide can prevent lutein oxidation, increase pigment deposition, and improve yolk color, with different doses showing varying degrees of Haugh unit improvement. Liu et al. [23] found that dietary Rehmannia polysaccharide significantly increased yolk color with increasing dosage, and plant polysaccharides can improve egg freshness to some extent. Wang et al. [21] demonstrated that alfalfa crude polysaccharide can improve the stability of carotenoids, increase pigment deposition in egg yolk, and improve yolk color while increasing Haugh unit and egg freshness in laying hens. Xin et al. [20] showed that alfalfa polysaccharide can significantly increase Haugh unit by affecting protein metabolism in eggs. In this study, dietary supplementation with different doses of Polygonatum polysaccharide improved quail yolk color and egg freshness, consistent with the above polysaccharide results. Previous reports have confirmed the antioxidant properties of Polygonatum polysaccharide [24], which can scavenge various free radicals in animals. We hypothesize that the improved egg quality is related to the antioxidant activity of Polygonatum polysaccharide.

3.3 Effects of Polygonatum Polysaccharide on Hatching Performance of Breeding Quails This study demonstrated that Polygonatum polysaccharide supplementation improved quail hatching performance. Shen et al. [25] reported that polysaccharides can enhance serum antioxidant activity, eliminate oxygen free radicals, and maintain vigorous reproductive capacity in laying hens. Zuo et al. [26] found that Astragalus polysaccharide can exert dual regulatory effects on estrogen and influence sex hormone secretion and metabolism. Liu [27] showed that alfalfa polysaccharide can regulate serum T-AOC, T-SOD, and GSH-Px activities and MDA content in laying hens, reduce lipid oxidation and liver damage, and alleviate oxidative stress. Additionally, studies have reported that Polygonatum polysaccharide has antibacterial and antiviral effects, effectively inhibiting the growth of *Escherichia coli*, *Salmonella*, *Staphylococcus aureus*, and *Bacillus cereus*, and can significantly improve the viability of Vero cells infected with herpes simplex virus, exerting protective effects on cells [28]. In this study, compared with the control group, both 0.4% and 0.8% Polygonatum polysaccharide significantly increased fertilization rate, hatching rate of fertilized eggs, and hatching rate of total eggs set, thereby improving hatching performance, which is consistent with the above reports. These effects may be related to Polygonatum polysaccharide' s ability to promote gonadal development, improve gonadal function, and its antioxidant, antibacterial, and antiviral activities.

3.4 Effects of Polygonatum Polysaccharide on Serum Antioxidant Indexes of Breeding Quails Xu [29] demonstrated that plant polysaccharides can enhance immunity by improving antioxidant capacity and eliminating reactive oxygen species. Dietary supplementation with alfalfa polysaccharide and Astragalus polysaccharide can significantly increase serum T-AOC and T-SOD and GSH-Px activities while reducing serum MDA content, with antioxidant effects showing a dose-response relationship. Wang et al. [22] found that dietary Astragalus polysaccharide can significantly increase serum T-SOD and GSH-Px activities and reduce MDA content, thereby enhancing antioxidant function. Zuo et al. [26] showed that dietary Astragalus polysaccharide can increase serum T-AOC, SOD, and GSH-Px activities and reduce serum MDA content in laying hens, with 0.4% Astragalus polysaccharide showing the best effects. Studies have reported that Polygonatum polysaccharide can not only scavenge hydroxyl radicals and superoxide anion radicals generated in in vitro chemical reactions but also inhibit lipid peroxidation [24,30], demonstrating its ability to improve antioxidant performance both in vivo and in vitro. This study showed that serum T-SOD, GSH-Px activities, and T-AOC increased with Polygonatum polysaccharide dosage, while serum MDA content decreased with increasing dosage, consistent with the above reports. These index changes clearly demonstrate that Polygonatum polysaccharide can alter the serum antioxidant capacity of breeding quails.

Conclusions

1. Dietary supplementation with 0.4% and 0.8% Polygonatum polysaccharide can significantly increase average egg weight and laying rate while significantly reducing ADFI and feed-to-egg ratio in breeding quails, with 0.4% Polygonatum polysaccharide showing the best effects.

2. Dietary supplementation with 0.4% and 0.8% Polygonatum polysaccharide can significantly increase yolk color and Haugh unit in breeding quails, with 0.4% Polygonatum polysaccharide showing the best effects.
3. Dietary supplementation with 0.4% and 0.8% Polygonatum polysaccharide can significantly increase fertilization rate, hatching rate of fertilized eggs, and hatching rate of total eggs set in breeding quails, with 0.4% Polygonatum polysaccharide showing the best effects.
4. Dietary supplementation with 0.4% and 0.8% Polygonatum polysaccharide can significantly improve serum antioxidant function in breeding quails, with effects showing dose-dependency.

We thank Professor Zhao Xiaoling from the College of Animal Science and Technology, Sichuan Agricultural University, for valuable comments on the manuscript.

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