

Effects of Supplementary Lighting Time and Intensity in Autumn and Winter on Laying Performance, Serum Physiological and Biochemical Indices, and Antioxidant Capacity of White King Pigeons (Postprint)

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Abstract

This experiment aimed to investigate the effects of different supplementary lighting durations and intensities during autumn and winter on the laying performance, serum physiological and biochemical indices, and antioxidant capacity of white-feathered king pigeons. A total of 280 healthy 8-month-old white-feathered king pigeons (all female) were paired into 140 pairs (i.e., 140 cages) and randomly allocated into 5 groups according to the principle of similar body weight, with 4 replicates per group and 7 cages (14 birds) per replicate. The supplementary lighting durations and intensities for each group were: 0 h, 0 lx; 4 h, 31.2 lx; 4 h, 20.5 lx; 6 h, 31.2 lx; and 6 h, 20.5 lx. The experimental period lasted 125 days. The results showed that: 1) The egg production rate in the 4 h, 20.5 lx and 6 h, 31.2 lx groups was significantly higher than that in the 0 h, 0 lx group ($P < 0.05$), while there were no significant differences in average daily feed intake or average egg weight among all groups ($P > 0.05$). 2) The serum immunoglobulin M content in the 6 h, 31.2 lx and 6 h, 20.5 lx groups was significantly lower than that in the 0 h, 0 lx group ($P < 0.05$). The serum aspartate aminotransferase activity in the 4 h, 31.2 lx, 4 h, 20.5 lx, 6 h, 31.2 lx, and 6 h, 20.5 lx groups was all higher than that in the 0 h, 0 lx group ($P > 0.05$). 3) There were no significant differences in serum prolactin (PRL), estradiol (E2), follicle-stimulating hormone, luteinizing hormone, and progesterone contents among all groups ($P > 0.05$). However, the serum PRL content in the 0 h, 0 lx group was higher than that in the other groups, while the serum E2 content was lower than that in the other groups. 4) Compared with the 0 h, 0 lx group, the serum superoxide dismutase activity in the 6 h, 31.2 lx group was significantly decreased ($P < 0.05$), while the serum malondialdehyde (MDA) content was significantly

increased ($P < 0.05$). The liver MDA content in the 0 h, 0 lx, 4 h, 20.5 lx, and 6 h, 20.5 lx groups was significantly lower than that in the 6 h, 31.2 lx group ($P < 0.05$). It can be concluded that when the supplementary lighting duration was 4 h and intensity was 20.5 lx, white-feathered king pigeons could achieve better laying performance. Excessively long supplementary lighting duration (6 h) and excessively high intensity (31.2 lx) could significantly reduce the antioxidant capacity of white-feathered king pigeons, and the supplementary lighting intensity should not exceed 20.5 lx.

Full Text

Effects of Supplementary Lighting Time and Intensity in Fall and Winter on Laying Performance, Serum Physiological and Biochemical Parameters, and Antioxidant Capacity of White King Pigeons

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Abstract

This experiment was conducted to investigate the effects of different supplementary lighting time and intensity on laying performance, serum physiological and biochemical parameters, and antioxidant capacity of White King pigeons during

fall and winter. Two hundred eighty healthy 8-month-old female pigeons were paired, yielding 140 pairs (140 cages). Based on similar body weight, these pairs were randomly allocated into five groups with four replicates each, with seven pairs (14 pigeons) per replicate. The supplementary lighting time and intensity for each group were: 0 h, 0 lx; 4 h, 31.2 lx; 4 h, 20.5 lx; 6 h, 31.2 lx; and 6 h, 20.5 lx. The experiment lasted 125 days. The results showed: (1) The laying rates in the 4 h, 20.5 lx and 6 h, 31.2 lx groups were significantly higher than in the 0 h, 0 lx group ($P < 0.05$), while no significant differences were observed among groups in average daily feed intake or average egg weight ($P > 0.05$). (2) Serum immunoglobulin M content in the 6 h, 31.2 lx and 6 h, 20.5 lx groups was significantly lower than in the 0 h, 0 lx group ($P < 0.05$). Serum aspartate transaminase activity in the 4 h, 31.2 lx, 4 h, 20.5 lx, 6 h, 31.2 lx, and 6 h, 20.5 lx groups was higher than in the 0 h, 0 lx group ($P > 0.05$). (3) No significant differences were found among groups in serum prolactin (PRL), estradiol (E2), follicle-stimulating hormone, luteinizing hormone, or progesterone content ($P > 0.05$). However, the 0 h, 0 lx group showed higher serum PRL content and lower serum E2 content compared to other groups. (4) Compared with the 0 h, 0 lx group, the 6 h, 31.2 lx group exhibited significantly decreased serum superoxide dismutase activity ($P < 0.05$) and significantly increased serum malondialdehyde (MDA) content ($P < 0.05$). Liver MDA content in the 0 h, 0 lx, 4 h, 20.5 lx, and 6 h, 20.5 lx groups was significantly lower than in the 6 h, 31.2 lx group ($P < 0.05$). In conclusion, White King pigeons achieved optimal laying performance with supplementary lighting of 4 h duration and 20.5 lx intensity. Excessively long lighting time (6 h) combined with high intensity (31.2 lx) significantly reduced antioxidant capacity, suggesting that supplementary lighting intensity should not exceed 20.5 lx.

Keywords: fall and winter; supplementary lighting; White King pigeon; laying performance; serum physiological and biochemical parameters; antioxidant capacity

Introduction

Light serves as a crucial regulatory factor that influences animal welfare and production performance by modifying animal behavior and physiological pathways [1]. Primarily, light information is transmitted through the nervous system or directly through the skull to the hypothalamus, subsequently regulating reproduction and growth control via the hypothalamic-pituitary-ovarian axis [2-3]. When photoperiod exceeds 12 hours, poultry exhibit increased laying rates, growth rates, and feed-to-weight ratios [4-5]. Niu et al. [6] reported that increasing light intensity from 9.15 lx to 19.51 lx significantly improved laying rates in caged laying hens. However, other researchers have found that excessively long and intense continuous lighting increases disease incidence and compromises animal welfare [7-9]. Guo et al. [10] also demonstrated that short-duration lighting and natural light were more conducive to stress resistance and immune

function in fast-growing yellow-feathered broilers. While numerous studies have examined lighting effects on laying hens, research on lighting regimes for pigeon farming remains scarce. Given that pigeon farming primarily employs semi-open housing systems, this experiment utilized artificial supplementary lighting with varying durations and intensities to comprehensively evaluate their effects on laying performance, serum physiological and biochemical parameters, and antioxidant capacity of White King pigeons. The objective was to explore the practical application of different supplementary lighting regimens and provide scientific evidence for lighting management in pigeon egg production.

1.1 Experimental Design

This study employed a two-factor experimental design with supplementary lighting time and intensity as the two factors. Two hundred eighty healthy 8-month-old White King pigeons (all female) were paired, forming 140 pairs housed in 140 cages. Based on similar body weight, these pairs were randomly divided into five groups (A, B, C, D, and E) with four replicates per group and seven pairs (14 pigeons) per replicate. Each group was separated by walls to prevent interference. Group A served as the control with no light bulbs installed (natural light only). Groups B and D had three 40 W bulbs installed per house, spaced 2 m apart, positioned above the aisle at 105 cm from the pigeons' backs, with average light intensity measured at four points being approximately 31.2 lx. Groups C and E had two 40 W bulbs installed per house, spaced 3 m apart, at the same height, with average intensity of approximately 20.5 lx. The supplementary lighting time and intensity for groups A through E were: 0 h, 0 lx; 4 h, 31.2 lx; 4 h, 20.5 lx; 6 h, 31.2 lx; and 6 h, 20.5 lx, respectively. Natural light duration was approximately 10 h for all groups. Supplementary lighting periods were 05:00–07:00 and 17:00–19:00 for groups B and C, and 04:00–07:00 and 17:00–20:00 for groups D and E. The experiment ran from September 1, 2015 to December 25, 2015 (125 days), with a 10-day pre-trial adaptation period. Pigeons were housed in cages throughout the study.

1.2 Basal Diet and Management

The basal diet was formulated according to NRC (1994) poultry nutrient requirements. Diet composition and nutrient levels are presented in Table 1, and nutrient grit composition is shown in Table 2. During the experiment, feeding occurred at 08:30 and 15:00 daily. Eggs were collected and weighed at 09:30. Pens, feeders, grit troughs, and waterers were cleaned regularly to maintain good ventilation and hygiene.

1.3 Measurements

1.3.1 Laying Performance Daily egg production, egg weight, and feed intake were accurately recorded for each group to calculate laying rate, average egg weight, and average daily feed intake. Laying rate (%) = (total eggs laid in 7 days / number of breeding pigeons per group) × 100; Average egg weight

(g) = total egg weight per group per day / total number of eggs per group per day; Average daily feed intake (g/d) = daily feed intake per group / number of breeding pigeons per group.

1.3.2 Serum Physiological and Biochemical Parameters After the feeding trial, two pigeons were randomly selected from each replicate per group. Blood samples were collected from the jugular vein, allowed to clot, and serum was carefully transferred to EP tubes. Serum was centrifuged at 3,000 r/min for 10 min at 4°C, and the supernatant was transferred to new EP tubes and stored at -20°C. Serum aspartate transaminase (AST), alanine transaminase (ALT) activities and albumin (ALB), total protein (TP), calcium, phosphorus, immunoglobulin A (IgA), immunoglobulin G (IgG), and immunoglobulin M (IgM) concentrations were measured. Additionally, serum prolactin (PRL), estradiol (E2), follicle-stimulating hormone (FSH), luteinizing hormone (LH), and progesterone (P) concentrations were determined. IgA, IgG, IgM, PRL, E2, FSH, LH, and P were measured by radioimmunoassay, while other parameters were measured by colorimetric methods. All analyses were performed by Beijing Huaying Biological Technology Research Institute.

1.3.3 Liver and Serum Antioxidant Indices After blood collection, pigeons were euthanized by exsanguination. The abdominal cavity was opened, and livers were removed and preserved in liquid nitrogen for analysis of total antioxidant capacity (T-AOC), superoxide dismutase (SOD), glutathione peroxidase (GSH-Px) activities, and malondialdehyde (MDA) and reduced glutathione (GSH) contents. Serum samples were prepared as described in section 1.3.2. All assay kits were purchased from Nanjing Jiancheng Bioengineering Institute.

1.4 Data Analysis

Data were processed and analyzed using Excel 2013 and SPSS 18.0 software. Results are expressed as mean \pm standard error (mean \pm SE). Duncan's multiple range test was used for significance comparison, with $P < 0.05$ considered statistically significant and $P > 0.05$ considered not significant.

Results

2.1 Effects of Different Supplementary Lighting Time and Intensity on Laying Performance of White King Pigeons

As shown in Table 3, different supplementary lighting time and intensity improved the laying rate of White King pigeons. The laying rates in the 4 h, 20.5 lx and 6 h, 31.2 lx groups were significantly higher than in the 0 h, 0 lx group ($P < 0.05$). The 4 h, 31.2 lx and 6 h, 20.5 lx groups also showed higher laying rates than the 0 h, 0 lx group, but the differences were not significant ($P > 0.05$). The highest laying rate was observed in the 4 h, 20.5 lx group. No significant effects of supplementary lighting time and intensity were observed on average

egg weight or average daily feed intake ($P>0.05$). However, average daily feed intake in the 4 h, 31.2 lx, 4 h, 20.5 lx, 6 h, 31.2 lx, and 6 h, 20.5 lx groups was higher than in the 0 h, 0 lx group.

2.2 Effects of Different Supplementary Lighting Time and Intensity on Serum Biochemical Parameters of White King Pigeons

As shown in Table 4 , serum IgM content gradually decreased with increasing lighting time, with the 6 h, 31.2 lx and 6 h, 20.5 lx groups showing significantly lower serum IgM content than the 0 h, 0 lx group ($P<0.05$). No significant differences were observed among groups in serum AST and ALT activities or ALB, TP, calcium, phosphorus, IgA, and IgG concentrations ($P>0.05$). However, serum AST activity in the 4 h, 31.2 lx, 4 h, 20.5 lx, 6 h, 31.2 lx, and 6 h, 20.5 lx groups was higher than in the 0 h, 0 lx group.

2.3 Effects of Different Supplementary Lighting Time and Intensity on Serum Physiological Parameters of White King Pigeons

As shown in Table 5 , different supplementary lighting time and intensity had no significant effects on serum PRL, E2, FSH, LH, and P concentrations ($P>0.05$). However, with changes in lighting time and intensity, the 0 h, 0 lx group showed higher serum PRL content, lower serum LH content, and lower serum E2 content compared to other groups.

2.4 Effects of Different Supplementary Lighting Time and Intensity on Antioxidant Capacity of White King Pigeons

As shown in Table 6 , serum SOD activity in the 4 h, 31.2 lx, 4 h, 20.5 lx, 6 h, 31.2 lx, and 6 h, 20.5 lx groups was lower than in the 0 h, 0 lx group, while serum MDA content was higher. Specifically, the 6 h, 31.2 lx group showed significantly lower serum SOD activity ($P<0.05$) and significantly higher serum MDA content ($P<0.05$) compared to the 0 h, 0 lx group. Liver MDA content in the 0 h, 0 lx, 4 h, 20.5 lx, and 6 h, 20.5 lx groups was significantly lower than in the 6 h, 31.2 lx group ($P<0.05$). No significant differences were observed among groups in other serum and liver antioxidant indices ($P>0.05$).

Discussion

3.1 Effects of Different Supplementary Lighting Time and Intensity on Laying Performance of White King Pigeons

In this study, different supplementary lighting time and intensity significantly affected the laying rate of White King pigeons but had no significant effects on average daily feed intake or average egg weight. The laying rates were significantly higher than the control group when lighting time and intensity were 4 h, 20.5 lx and 6 h, 31.2 lx. Shen et al. [11] reported that Beijing You chickens under 14 h continuous lighting showed significantly higher laying rates during both

peak and late laying periods compared to those under 16 h continuous lighting. However, Siopes [12] found that increasing photoperiod from 15 h to 18 h during summer egg production in turkeys improved laying rate without affecting egg weight, while increasing light intensity from 22 lx to 567 lx decreased egg weight without significantly affecting laying rate. This suggests that long photoperiod promotes egg production while high light intensity reduces egg weight. Similar results were reported by Renema et al. [13], who found that hens could lay eggs at light intensities between 1-500 lx, but egg production decreased at 1 lx and egg weight decreased at 500 lx. Wang et al. [14] reported that supplementary lighting to 13.5 h in winter significantly increased egg production and laying rate in geese and extended the laying period by one month. However, Proudman and Siopes [15] found that reducing photoperiod by 4.5 h (from 18.0 h to 11.5 h) for two weeks did not significantly affect laying performance compared to the 18 h group. Due to species differences and varying management practices, the effects of different lighting time and intensity on poultry laying performance are inconsistent. In this experiment, White King pigeons achieved the highest laying rate with supplementary lighting of 4 h duration and 20.5 lx intensity.

3.2 Effects of Different Supplementary Lighting Time and Intensity on Serum Biochemical Parameters of White King Pigeons

Serum TP and ALB concentrations are indicators of normal kidney and liver function, while serum globulin concentration is closely related to immune function [16]. Huang et al. [17] found that 17 h lighting significantly reduced serum TP and globulin concentrations compared to 13 h lighting in laying hens. Guo et al. [18] reported that broilers under continuous lighting (23 h) had significantly lower serum IgG concentrations than those under intermittent lighting. This study found no significant effects on serum TP and ALB concentrations, but serum IgM content in the 6 h, 31.2 lx and 6 h, 20.5 lx groups was significantly lower than in the 0 h, 0 lx group. The 4 h, 31.2 lx and 4 h, 20.5 lx groups showed no significant differences in serum IgM content compared to the 0 h, 0 lx group, indicating that the reduction in serum IgM content was caused by excessively long lighting time (6 h) rather than lighting intensity. Whether excessively long lighting time reduces immune function in White King pigeons requires further investigation.

ALT and AST are important enzymes in hepatocytes. When liver cells are damaged, increased cell membrane permeability allows these enzymes to enter the bloodstream, resulting in significantly increased serum ALT and AST activities. However, as key enzymes in amino acid metabolism, ALT and AST activities also reflect protein metabolism status [19]. Pan [20] found that serum ALT activity decreased with increasing lighting time, suggesting reduced protein metabolism capacity in late laying period of hens. This study found higher serum AST activity in the 4 h, 31.2 lx, 4 h, 20.5 lx, 6 h, 31.2 lx, and 6 h, 20.5 lx groups compared to the 0 h, 0 lx group, possibly because supplementary lighting enhanced protein synthesis and metabolism in White King pigeons. Further ver-

ification is needed to determine other potential effects of artificial supplementary lighting on the liver of White King pigeons.

3.3 Effects of Different Supplementary Lighting Time and Intensity on Serum Physiological Parameters of White King Pigeons

LH and FSH work synergistically during reproduction to promote ovarian growth and maturation and stimulate estrogen secretion, thereby inducing ovulation. E2 also provides feedback regulation on LH and FSH synthesis and secretion to improve laying performance [21]. PRL plays an important role in reproduction; high PRL concentrations in birds primarily inhibit follicular development and gonadotropin-releasing hormone (GnRH) secretion to induce broodiness, while low PRL concentrations promote egg production, though the specific threshold remains unclear [22-23]. Bacon et al. [24] reported that increasing photoperiod from 8 h to 14 h in turkeys resulted in higher serum LH concentrations than the 8 h group, with serum LH remaining elevated during the dark period. Sharp et al. [25] found that birds under long-day conditions showed slowly increasing serum PRL concentrations that did not reach levels inhibitory to hypothalamic GnRH secretion, resulting in simultaneous elevation of serum PRL and LH. No reports have addressed lighting intensity effects on poultry hormone concentrations. This study found no significant differences in serum physiological parameters among groups, but the 0 h, 0 lx group showed lower serum LH and E2 concentrations and higher serum PRL concentration compared to other groups, while lighting intensity showed no consistent effect on reproductive hormone secretion in White King pigeons.

3.4 Effects of Different Supplementary Lighting Time and Intensity on Antioxidant Capacity of White King Pigeons

Animals have evolved enzymatic and non-enzymatic antioxidant systems that maintain a dynamic balance between free radical generation and elimination. Major antioxidant enzymes include SOD, GSH-Px, and catalase (CAT), while non-enzymatic antioxidants include GSH, vitamin E, and selenium [26]. T-AOC is a comprehensive indicator of antioxidant capacity, and MDA is a product of lipid peroxidation resulting from free radical attack on unsaturated fatty acids in biological membranes; its concentration reflects the degree of oxygen radical-mediated lipid peroxidation. Li et al. [27] found that long photoperiod reduced serum SOD activity and increased MDA content, while intermittent lighting decreased lipid peroxidation, increased antioxidant enzyme activity, and reduced serum MDA content in broilers. Guo et al. [18] also reported that long photoperiod reduced antioxidant capacity in broilers. These findings align with our results: the 6 h, 31.2 lx group showed significantly lower serum SOD activity and significantly higher serum MDA content compared to the 0 h, 0 lx group, and liver MDA content in the 6 h, 31.2 lx group was significantly higher than in the 0 h, 0 lx, 4 h, 20.5 lx, and 6 h, 20.5 lx groups. This may be because excessively long (6 h) and high-intensity (31.2 lx) lighting exposure placed White King pi-

geons under stress, leading to excessive free radical production and disrupting the balance between oxidation and antioxidation, thereby reducing antioxidant capacity. Therefore, excessively long lighting time (6 h) decreased antioxidant capacity, and the optimal supplementary lighting time in this study was 4 h.

Conclusion

Based on the experimental results, two key conclusions can be drawn: First, White King pigeons achieve optimal laying performance with supplementary lighting of 4 h duration and 20.5 lx intensity. Second, excessively long lighting time (6 h) combined with high intensity (31.2 lx) significantly reduces antioxidant capacity in White King pigeons, indicating that supplementary lighting intensity should not exceed 20.5 lx.

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