Effects of Light Intensity on Production Performance, Carcass Traits, and Meat Quality of Pekin Ducks (Postprint)

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Abstract

This study aimed to investigate the effects of light intensity on production performance, carcass characteristics, and meat quality of Beijing ducks. A total of 600 healthy 1-day-old Beijing ducks were randomly allocated to 5 groups, with 4 replicates per group and 30 ducks per replicate (half male and half female). The light intensity for each experimental group was set at 1, 5, 10, 15, and 40 lx, respectively, with 24-hour full artificial lighting using incandescent lamps. The experimental period lasted for 6 weeks. The results showed: 1) During weeks 1-6, there were no significant differences in average feed consumption and average body weight gain among groups ($P>0.05$), while the feed conversion ratio of the 5 lx group was significantly lower than that of the 10, 15, and 40 lx groups ($P<0.05$). During the brooding period (weeks 1-2) and growing period (weeks 3-5), there were no significant differences in production performance among groups ($P>0.05$), while during the finishing period (week 6), the average feed consumption and average body weight gain of the 1 lx group were significantly higher than those of the 5, 10, and 15 lx groups ($P<0.05$). 2) Light intensity had no significant effects on dressing percentage, eviscerated yield, leg muscle percentage, abdominal fat percentage, and eyeball indices (weight, transverse diameter, and anteroposterior diameter) ($P>0.05$), but the breast muscle percentage of the 5 lx group was significantly higher than that of the 40 lx group ($P<0.05$). 3) Light intensity had no significant effects on ultimate pH (pHu), drip loss rate, and b* value (yellowness) ($P>0.05$); the initial pH (pHi) of the 40 lx group was significantly higher than that of the 5, 10, and 15 lx groups ($P<0.05$), but its L* value (lightness) was significantly lower than that of the 5, 10, and 15 lx groups ($P<0.05$). The a* values (redness) of the 15 and 40 lx groups were significantly lower than that of the 1 lx group ($P<0.05$). In conclusion, a light intensity of 5 lx is not only energy-efficient but also can improve feed conversion ratio and breast muscle percentage in Beijing ducks. Additionally, low light intensity helps improve L* and a* values of meat color.

Full Text

Effects of Light Intensity on Performance, Carcass Performance and Meat Quality of Peking Ducks

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Abstract

This study investigated the effects of light intensity on the performance, carcass performance, and meat quality of Peking ducks. Six hundred healthy 1-day-old Peking ducks were randomly allocated to five groups, with four replicates per group and 30 ducks per replicate (half male and half female). The experimental light intensities were set at 1, 5, 10, 15, and 40 lx, provided by incandescent lamps with 24-hour artificial lighting. The experimental period lasted for six weeks. The results showed: (1) For weeks 1–6, there were no significant differences in average feed intake or average body weight gain among groups ($P>0.05$), but the feed-to-gain ratio of the 5 lx group was significantly lower than that of the 10, 15, and 40 lx groups ($P<0.05$). No significant differences in performance were observed during the brooding period (weeks 1–2) and growing period (weeks 3–5) ($P>0.05$). However, during the fattening period (week 6), the average feed intake and average body weight gain of the 1 lx group were significantly higher than those of the 5, 10, and 15 lx groups ($P<0.05$). (2) Light intensity had no significant effect on dressing percentage, eviscerated percentage, thigh meat percentage, abdominal fat percentage, or ocular indices (weight, transverse diameter, and anteroposterior diameter) ($P>0.05$), but the breast muscle percentage of the 5 lx group was significantly higher than that of the 40 lx group ($P<0.05$). (3) Light intensity had no significant effect on ultimate pH (pHu), drip loss rate, or yellowness (b*) value ($P>0.05$). The initial pH (pHi) of the 40 lx group was significantly higher than that of the 5, 10, and 15 lx groups ($P<0.05$), while its lightness (L)* value was significantly lower than that of the 5, 10, and 15 lx groups ($P<0.05$). The redness (a*) values of the 15 and 40 lx groups were significantly lower than that of the 1 lx group ($P<0.05$).

In conclusion, a light intensity of 5 lx not only saves energy effectively but also improves feed conversion ratio and breast muscle percentage in Peking ducks. Additionally, low light intensity helps enhance the L* and a* values of meat color.

Keywords: light intensity; performance; carcass performance; meat quality; Peking ducks

Introduction

As livestock and poultry production moves toward intensification, scaling-up, and standardization, producers raising fast-growing broiler poultry always expect to maximize production efficiency in the shortest possible time. However, this approach in actual production leads to reduced physical health and disease resistance in poultry, triggering negative effects such as skeletal deformities, metabolic diseases, and sudden death syndrome [1-3]. Therefore, research and application of the interaction mechanisms between production environment and nutrition have become exceptionally important. As a crucial environmental factor, lighting plays a key role in livestock and poultry production management. Studies have shown that lighting environment can directly or indirectly affect poultry production performance [4], immune function [5], and reproductive system development [6]. Researching and optimizing lighting environments to improve light source utilization efficiency and reduce electricity consumption also holds significant importance for energy conservation and emission reduction [7].

Light intensity, as an important component of lighting environment, also affects broiler chicken production performance and carcass performance. Some studies have found that light intensity has no significant effect on broiler body weight or feed consumption [8-9], but dressing percentage and thigh meat percentage are negatively correlated with light intensity, with the wing-to-live-weight ratio being highest at 1 lx light intensity [8]. Additionally, when light intensity is low, reduced activity helps broilers deposit fat during the fattening period, but excessively low light increases the probability of leg and eye diseases [10]. Conversely, when light intensity is too high, increased flock activity can cause severe pecking and prolapse [11].

However, among the numerous reported studies on lighting in broiler poultry, most have focused on broiler chickens, with few reports on other breeds such as ducks. As a typical Chinese duck breed, Peking duck production has been increasing annually with growing intensification, yet standardized lighting parameters have not been established. Therefore, studying the effects of light intensity on production performance, carcass performance, and meat quality in Peking ducks holds important theoretical value and practical significance. This experiment selected Peking ducks as subjects to investigate the effects of different light intensities on their production performance, carcass performance, and meat quality, aiming to provide reliable lighting parameters for Peking duck production.

1.1 Experimental Animals and Design

Six hundred 1-day-old Peking ducks from the same hatch, healthy, with an average body weight of (54.86$±$3.32) g, were selected for the experiment (300 males and 300 females). A single-factor randomized block design was adopted. Following the "Feeding Standard of Meat Ducks" [12], five light intensity groups

were established: 1, 5, 10, 15, and 40 lx. Each group contained four replicates with 30 ducks per replicate (half male and half female). The experimental period was six weeks. Incandescent lamps served as the light source, with five lamps installed in each compartment at 2.5 m above ground level and 1.5 m from the rearing nets, spaced 1.5 m apart. A light controller regulated the photoperiod at 24-hour artificial lighting, and a light intensity regulator adjusted the intensity. A light intensity meter was used to measure and calibrate the intensity in each compartment once every three days. Light intensity values were measured at feeder positions, with five measurement points per detection, maintaining a coefficient of variation within 15% [13].

1.2 Feeding Management

The experimental duck house was located at Chengyuan Shenglong Breeding Co., Ltd. in Changping District, Beijing. The duck house measured 12.0 m × 8.5 m and was fully enclosed. Dark shading cloth divided the house into five compartments of equal area, each with different light intensity. Ducks were raised on net floors, with all five compartments maintaining good ventilation and consistent temperature and humidity (automatically controlled by heating furnaces and fans). Water was supplied through unified water lines, and feed was provided manually. Ducks had ad libitum access to feed and water. The basal diet composition and nutrient levels are shown in Table 1 .

1.3 Measurements

1.3.1 Performance Indicators At the end of weeks 2, 5, and 6, feed was withdrawn at 18:00, and duck body weight was measured at 06:00 the following day. Feed intake and body weight gain were recorded to calculate average feed intake, average body weight gain, and feed-to-gain ratio for weeks 1–2, 3–5, week 6, and weeks 1–6.

1.3.2 Carcass Performance Indicators At six weeks of age, six ducks were randomly selected from each replicate (half male and half female) for weighing and slaughter. Slaughter procedures followed the "Poultry Production Performance Terminology and Measurement Methods" [14] to calculate dressing percentage, eviscerated percentage, breast meat percentage, thigh meat percentage, and abdominal fat percentage. During slaughter, the left eyeball of each Peking duck was extracted, adherent tissues were completely removed, and the eyeball was immediately weighed and measured for transverse and anteroposterior diameters.

1.3.3 Meat Quality Indicators After slaughter, the left breast muscle was collected to determine meat color, drip loss rate, and pH. Meat color was measured one hour post-slaughter using a portable colorimeter, recording lightness (L*), redness (a*)*, and yellowness (b*) values. Drip loss rate was determined following the method of Rasmussen et al. [15]. Approximately 2 g of breast muscle

was sampled, stored at 4 °C for 24 hours, and weighed before and after storage to calculate drip loss rate. A portable pH meter measured initial pH (pHi) and ultimate pH (pHu) at the same location on the breast muscle at 1 and 24 hours post-slaughter, respectively.

1.4 Data Processing and Analysis

Excel and SAS 9.2 statistical software were used for data processing and analysis. Outliers and values exceeding three standard deviations from the mean were removed for blood indicator analysis. All data were tested for normal distribution using Pro Univariate (SAS 9.2). Variables with Shapiro-Wilk test W$ 0.98$were considered normally distributed; non-normal variables were log-transformed before analysis. One-way ANOVA was performed on experimental data from each group, followed$ 0.05$. Data are expressed as means ± $standard deviation.

Results

2.1 Performance Indicators

According to the "Feeding Standard of Meat Ducks," the feeding period for commercial Peking ducks is divided into three stages: brooding period (weeks 1–2), growing period (weeks 3–5), and fattening period (week 6) [12]. Table 2 shows the effects of light intensity on average feed intake of Peking ducks at different growth stages. During the brooding period, the 40 lx group had higher average feed intake than other groups, but the difference was not significant ($P>0.05$). During the growing and fattening periods, the 1 lx group showed higher values than other groups, particularly during the fattening period, where it was significantly higher than the 5, 10, and 15 lx groups ($P<0.05$). Overall, for the entire growth stage (weeks 1–6), light intensity had no significant effect on average feed intake ($P>0.05$).

Table 3 presents the effects of light intensity on average body weight gain of Peking ducks at different growth stages. No significant differences in average body weight gain were observed among groups during the brooding and growing periods ($P>0.05$). However, during the fattening period, the 1 lx group showed significantly higher average body weight gain than the 5, 10, and 15 lx groups, while the 40 lx group was also significantly higher than the 10 lx group ($P<0.05$). No significant differences were found among groups for the entire growth stage (weeks 1–6) ($P>0.05$), though the 1 lx group consistently showed higher average body weight gain across all stages, suggesting a trend toward promoting weight gain under low light intensity.

Table 4 illustrates the effects of light intensity on feed-to-gain ratio of Peking ducks at different growth stages. Light intensity significantly affected feed-to-gain ratio for the entire growth stage (weeks 1–6) ($P<0.05$), with the 10, 15, and 40 lx groups showing significantly higher ratios than the 5 lx group ($P<0.05$). However, no significant differences were observed among groups during each

individual growth stage (brooding, growing, and fattening periods) ($P>0.05$). These results indicate that, for the overall growth stage, a light intensity of 5 lx is more beneficial for improving feed conversion efficiency.

2.2 Carcass Performance Indicators

Table 5 shows the effects of light intensity on carcass performance of Peking ducks. Light intensity had no significant effect on dressing percentage, eviscerated percentage, thigh meat percentage, or abdominal fat percentage ($P>0.05$). However, the breast meat percentage of the 5 lx group was significantly higher than that of the 40 lx group ($P<0.05$). Additionally, the 5 lx group showed higher dressing percentage, eviscerated percentage, and thigh meat percentage than other groups, while maintaining lower abdominal fat percentage.

Table 6 presents the effects of light intensity on eye development in Peking ducks. No significant differences were found in eye weight, transverse diameter, or anteroposterior diameter among groups ($P>0.05$).

2.3 Meat Quality Indicators

Table 7 shows the effects of light intensity on meat quality of Peking ducks. Light intensity had no significant effect on pHu, drip loss rate, or b* value ($P>0.05$). However, the pHi of the 40 lx group was significantly higher than that of the 5, 10, and 15 lx groups ($P<0.05$). In terms of meat color values, the L* value of the 40 lx group was significantly lower than that of the 5, 10, and 15 lx groups ($P<0.05$). The 15 lx group showed the lowest a* value, which was significantly lower than that of the 1, 5, and 10 lx groups ($P<0.05$). The 1 lx group had the highest a* value, while the 40 lx group also showed significantly lower a* value than the 1 lx group ($P<0.05$).

Discussion

3.1 Performance Indicators

Numerous studies have investigated the effects of light intensity on production performance in fast-growing poultry, but research has primarily focused on broiler chickens, with few studies on other species. Even among broiler studies, results have been inconsistent. Ahmad et al. [9] reported that light intensities of 5–40 lx showed no significant differences in body weight or feed consumption, but the 5 lx group demonstrated significantly better feed conversion ratio than other groups. Deep et al. [8] also found that light intensities of 1–40 lx had no significant effect on broiler weight gain, feed intake, feed-to-gain ratio, or mortality. Blatchford et al. [16] similarly observed no significant effect of light intensity on feed intake in white-feathered broilers. In comparisons between high-intensity groups (100, 150 lx) and low-intensity groups (1, 5 lx), Charles et al. [17] found that low-intensity groups showed significantly higher weight gain,

attributing this to reduced activity and energy expenditure under excessive light intensity.

This experiment, using incandescent lamps to explore the effects of light intensity on Peking duck performance, found that light intensities of 1–40 lx had no significant effect on average feed intake or average body weight gain across the entire growth stage. However, the feed-to-gain ratio of the 5 lx group was significantly lower than that of the 10, 15, and 40 lx groups, reflecting that 5 lx improves feed conversion efficiency in Peking ducks—consistent with the findings of Ahmad et al. [9]. Other studies have indicated that 5 lx light intensity is more conducive to foraging and activity in quality broiler chickens during growing and fattening periods [18]. Additionally, this experiment found that the 1 lx group showed significantly higher average feed intake and average body weight gain during the fattening period compared to the 5, 10, and 15 lx groups. This suggests that the effect of light intensity on Peking ducks may have a cumulative effect, with non-significant impacts during weeks 1–5 that only become apparent at week 6. Due to the short growth cycle of Peking ducks, light intensity did not cause significant differences in overall production performance across the entire growth stage.

3.2 Carcass Performance Indicators

Dressing percentage, eviscerated percentage, breast meat percentage, and thigh meat percentage are primary indicators for evaluating meat production performance, while abdominal fat represents the main fat deposition site, accounting for approximately 22% of total body fat. Numerous studies have found that light intensity has no significant effect on carcass performance in white-feathered broilers and Beijing oil chickens [8, 19-20]. In this experiment, light intensities of 1–40 lx showed no significant effect on dressing percentage, eviscerated percentage, thigh meat percentage, or abdominal fat percentage in Peking ducks. Notably, the 5 lx group demonstrated higher dressing percentage, eviscerated percentage, and thigh meat percentage than other groups, along with lower abdominal fat percentage. Furthermore, the breast meat percentage of the 5 lx group was significantly higher than that of the 40 lx group. These results indicate that 5 lx light intensity offers advantages for carcass performance in Peking ducks.

Continuous dim lighting can cause morphological changes in eye structure, leading to retinopathy, enophthalmos, myopia, and blindness [21], possibly because prolonged light exposure disrupts the growth rhythm of the eyeball, causing corneal flattening and axial elongation [22]. Blatchford et al. [16] found that eye weight in the 5 lx group was significantly greater than in the 50 and 200 lx groups, though no significant differences were observed in transverse or anteroposterior diameters. In turkeys, Siopes et al. [23] found that low-light groups (1, 11 lx) showed abnormal eye development, with greater eye weight, transverse diameter, and anteroposterior diameter than high-light groups (110, 220 lx). This experiment found no significant differences in eye weight, transverse diameter,

or anteroposterior diameter among groups, suggesting that Peking ducks differ from broiler chickens in light intensity sensitivity and do not exhibit morphological changes in eye structure.

3.3 Meat Quality Indicators

pH is an important indicator reflecting the rate of muscle glycogen glycolysis post-slaughter and serves as a criterion for determining meat quality normality [24]. After slaughter, anaerobic glycolysis of muscle glycogen produces lactic acid, causing pH to decrease. In this study, the pHi of the 40 lx group at 1 hour post-slaughter was significantly higher than that of the 5, 10, and 15 lx groups, and its pHu at 24 hours was also higher than other groups, though not significantly. This may be because ducks in the 40 lx group had higher activity levels, resulting in greater glycogen consumption for movement and lower glycogen storage compared to other groups—consistent with the findings of Hua Dengke [13]. Drip loss rate is commonly used as an indicator of muscle water-holding capacity, with lower drip loss indicating greater water-holding capacity. In this experiment, no significant differences were observed in 24-hour drip loss rate among groups, indicating that light intensities of 1–40 lx had no significant effect on muscle water-holding capacity in Peking ducks.

Meat color is measured by L, *a*, and b* values. The L* value is influenced by meat color saturation and measurement lighting conditions, the a* value is affected by myoglobin status and reflects muscle freshness, and the b* value is influenced by the amount of sulfmyoglobin produced from reactions between myoglobin and bacterial metabolites [25]. In this experiment, the L* value of the 40 lx group was significantly lower than that of the 5, 10, and 15 lx groups, while the 1 lx group showed significantly higher a* value than the 15 and 40 lx groups. These results indicate that 40 lx light intensity reduces both L* and a* values in meat, while low light intensity (1, 5, 10 lx) helps maintain bright red and fresh meat color. These findings differ from Hua Dengke [13], who reported no significant effect of light intensity on meat color in Beijing oil chickens, possibly due to breed differences. Compared with yellow-feathered broilers, Peking ducks have a shorter growth cycle and faster muscle and fat deposition.

Conclusion

Light intensity does not significantly affect the production performance and carcass performance of Peking ducks, but 5 lx light intensity can improve feed conversion ratio and offers advantages for carcass performance. Low light intensity can also enhance the L* and a* values of meat color. Additionally, low light intensity effectively saves energy and reduces electricity consumption.

References

[1] CHEN Jilan, ZHU Jing, TANG Shi. Research and application of lighting programs in broiler chickens[J]. China Poultry, 2011, 33(20): 1–4.

[2] SCHWEAN-LARDNER K, FANCHER B I, CLASSEN H L. Impact of daylength on the productivity of two commercial broiler strains[J]. British Poultry Science, 2012, 53(1): 7–18.

[3] TANG Shi. Effects of different lighting schedules and nutrient levels on growth performance, sexual development and welfare of yellow-feathered broilers[D]. Master' s Thesis. Beijing: Chinese Academy of Agricultural Sciences, 2013.

[4] LI W B, GUO Y L, CHEN J L, et al. Influence of lighting schedule and nutrient density in broiler chickens: effect growth performance, carcass traits quality[J]. Asian-Australasian Journal of Animal Sciences, 2010, 23(11): 1510–1518.

[5] XIE Dian, CHEN Yaoxing, WANG Zixu, et al. Alleviating effect of blue light on immune stress in broilers[J]. Chinese Journal of Veterinary Science, 2008, 28(3): 325–327, 332.

[6] LI Yunlei, SUN Yanyan, HUA Dengke, et al. Effects of different light colors on production performance, carcass performance and sexual development of yellow-feathered broilers[J]. Acta Veterinaria et Zootechnica Sinica, 2015, 46(7): 1169–1175.

[7] XIN Hairui, XIONG Benhai, PAN Xiaohua, et al. Research progress on effects of lighting on fast-growing meat poultry[J]. Journal of Domestic Animal Ecology, 2015, 36(10): 1–6.

[8] DEEP A, SCHWEAN-LARDNER K, CROWE T G, et al. Effect of light intensity on broiler production, processing characteristics, and welfare[J]. Poultry Science, 2010, 89(11): 2326–2333.

[9] AHMAD F, HAQ A U, ASHRAF M, et al. Effect of different light intensities on the production performance of broiler chickens[J]. Pakistan Veterinary Journal, 2011, 31(3): 203–206.

[10] LIEN R J, HESS J B, MCKEE S R, et al. Effect of light intensity and photoperiod on live performance, heterophil-to-lymphocyte ratio, and processing yields of broilers[J]. Poultry Science, 2007, 86(7): 1287–1293.

[11] KRISTENSEN H H, AERTS J M, LEROY T, et al. Modelling the dynamic activity of broiler chickens in response to step-wise changes in light intensity[J]. Applied Animal Behaviour Science, 2006, 101(1/2): 125–143.

[12] Ministry of Agriculture of the People' s Republic of China. NY/T 2122-2012 Feeding standard of meat ducks[S]. Beijing: China Agriculture Press, 2012.

[13] HUA Dengke. Effects of different light intensities and dietary nutrient levels on production performance, meat quality and welfare of Beijing oil chickens[D]. Master' s Thesis. Yangzhou: Yangzhou University, 2014.

[14] Ministry of Agriculture of the People' s Republic of China. NY/T 823-2004 Poultry production performance terminology and measurement methods[S].

Beijing: China Agriculture Press, 2004.

[15] RASMUSSEN A J, ANDERSSON M. New method for determination of drip loss in pork muscles[C]//Meat for the Consumer, Proceedings of the 42nd International Congress on Meat Science and Technology. Lillehammer, Norway: Matforsk, 1996: 286-287.

[16] BLATCHFORD R A, KLASING K C, SHIVAPRASAD H L, et al. The effect of light intensity on the behavior, eye and leg health, and immune function of broiler chickens[J]. Poultry Science, 2009, 88(1): 20-28.

[17] CHARLES R G, ROBINSON F E, HARDIN R T, et al. Growth, body composition, and plasma androgen concentration of male broiler chickens subjected to different regimens of photoperiod and light intensity[J]. Poultry Science, 1992, 71(10): 1595-1605.

[18] HE Haijun, LI Dongli, HUA Dengke, et al. Effects of light intensity on production and slaughter performance of quality broilers[C]//Proceedings of the 9th Representative Meeting and 16th National Poultry Academic Symposium of the Poultry Science Branch of Chinese Association of Animal Science and Veterinary Medicine. Yangzhou: Chinese Association of Animal Science and Veterinary Medicine, 2013.

[19] DOWNS K M, LIEN R J, HESS J B, et al. The effects of photoperiod length, light intensity, and feed energy on growth responses and meat yield of broilers[J]. The Journal of Applied Poultry Research, 2006, 15(3): 406-416.

[20] HUA Dengke, LI Dongli, SUN Yanyan, et al. Effects of light intensity on hormone secretion, production performance and carcass performance of Beijing oil chickens[J]. Acta Veterinaria et Zootechnica Sinica, 2014, 45(5): 775-780.

[21] BUYSE J, SIMONS P C M, BOSHOUWERS F M G, et al. Effect of intermittent lighting, light intensity and source on the performance and welfare of broilers[J]. World' s Poultry Science Journal, 1996, 52(2): 121-130.

[22] WU Xiaomin. Effects of photoperiod and light intensity on eyeball development and refractive status in mice[D]. Master' s Thesis. Wenzhou: Wenzhou Medical College, 2008.

[23] SIOPES T D, TIMMONS M B, BAUGHMAN G R, et al. The effect of light intensity on the growth performance of male turkeys[J]. Poultry Science, 1983, 62(12): 2336-2342.

[24] TIAN Ying, LIU Xianjun, BIAN Lianquan, et al. Effects of carnosine and vitamin E on meat quality and antioxidant capacity of finishing pigs[J]. Chinese Journal of Animal Nutrition, 2014, 26(12): 3723-3730.

[25] HONG Ping, JIANG Zongyong, JIANG Shouqun, et al. Effects of dietary vitamin A supplementation level on growth performance and antioxidant indices of yellow-feathered broilers aged 43-63 days[J]. Chinese Journal of Animal Nutrition, 2013, 25(2): 415-426.