

The effects of monochromatic LED light from one to 14 days of age on the growth, muscle development, and blood parameters of goslings

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Abstract

This study was conducted to investigate the effects of monochromatic light on the growth performance, muscle development, and blood parameters of goslings from one to 14 days of age. A total of 192 male Sichuan White goslings were randomly assigned at hatching to four treatment groups of 48 birds, with six replications per group. These treatment groups were exposed to white light, red light, green light, or blue light in four environmentally controlled chambers. At 14 days of age, body weight and feed intake were determined on a per-pen basis, and one gosling per pen was selected for the collection of blood and muscle samples. All data were subjected to an analysis of variance. The results showed that the blue and green light groups had lower average daily feed intake and feed/gain ratios than the red and white light groups, but no differences in average daily gain and final body weight were found. Moreover, the leg muscle weight and leg muscle fibre diameter and density were unaffected by exposure to monochromatic light. Similarly, the goslings from the four treatment groups exhibited comparable plasma levels of growth hormone, insulin-like growth factor 1, immunoglobulin Y, and immunoglobulin M. Our study indicates that short-term exposure to different light colours does not affect the growth of goslings, but light with short wavelengths decreases feed intake and improves feed conversion efficiency.

Keywords: geese, light-emitting diode, muscle, performance

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Introduction

With the development of the modern poultry industry, increasing attention has been paid to the impact of environmental factors on poultry growth. Light is an important environmental factor that has a significant effect on many aspects of bird life, including production, physiology, welfare, and behaviour (Reonato Franco *et al.*, 2022). Light-emitting diode (LED) lights are increasingly used in poultry production because of their controllable wavelength and power, low power consumption, high energy conversion efficiency, long life, low cost, and easy maintenance (Morrill *et al.*, 2014). Furthermore, LED lights have attracted the attention of poultry scientists as sources of monochromatic light. Previous

reports have confirmed that red LED lights have a positive influence on the reproductive performance of poultry, elevating circulating oestradiol levels, extending the laying period, and increasing the number of eggs produced (Hubereicher *et al.*, 2013; Baxter *et al.*, 2014; Chang *et al.*, 2016). Additionally, studies in broilers have shown that blue or green lights improve growth performance, immunity, meat quality, and meat yield (Cao *et al.*, 2008; Ke *et al.*, 2011; Hassan *et al.*, 2014; Morrill *et al.*, 2014; Jian *et al.*, 2015). In contrast, ducks exposed to long-wavelength light may have faster growth rates than those exposed to short-wavelength light. Cambell *et al.* (2015) found that ducks reared under red or white compact fluorescent lamp light were heavier than those reared under blue light.

Kim *et al.* (2014) reported that ducks exposed to blue, green, white, and red light had comparable body weights (BW) and feed conversion ratios (FCR) during the early stages of growth (one to three weeks of age), but ducks exposed to green and red light had higher BWs and greater weight gain during the later stages of growth (four to six weeks of age). However, the results of previous studies have been inconsistent. House *et al.* (2021a,b) reported that BWs and FCRs in ducks were not affected by different monochromatic LED light colours or mixed LED light colours. Firouzi *et al.* (2014) also found no significant differences in the 42-day BWs of broilers reared under blue, green, red, or yellow light. In geese, Chang *et al.* (2016) found that Roman breeder geese exposed to white, blue, or red LED light had comparable growth performances. Similarly, Li *et al.* (2020) found that although meat geese reared under blue light had numerically higher BWs than those reared under white and red lights during the early stages of growth (14 to 42 days of age), this difference was not statistically significant. However, at 63 days of age, the red-light group had a significantly higher BW than the blue light group (Li *et al.*, 2020).

Nevertheless, these studies did not measure performance at an early stage, and little information has been published regarding the effects of light colour on goslings. Despite extensive research on the impacts of LED lighting on various poultry species, the effect on goslings, particularly in their early stages of growth, remains underexplored. Some conflicting reports concerning the effects of monochromatic light on bird growth indicate that more research is needed to support the application of monochromatic light in poultry production. Therefore, the objective of this study was to investigate the effects of different monochromatic LED lights on the growth performance, muscle development, and blood parameters related to growth and immunity of goslings from one to 14 days of age.

Materials and methods

The experimental procedures described were approved by the Chinese Chongqing Academy of Animal Science (CAAS) Animal Ethics Committee (ethical clearance number: XKY-20230420).

All the geese used in this study were obtained from the goose-breeding centre of CAAS. A total of 192 one-day-old male Sichuan White goslings were randomly assigned to one of four treatment groups, with six replicate pens and eight birds per pen in each treatment group. All pens had similar average initial BWs (IBW: 78.98 ± 0.30 g) at the start of the experiment. The goslings were housed in four environmentally controlled chambers, and each chamber was equipped with an independent monochromatic LED lighting system. The LED lighting systems provided four different monochromatic lights: white light (400 to 700 nm), red light (660 nm), green light (560 nm), and blue light (480 nm). The LED lamps were placed 80 cm above the heads of the goslings. To ensure that all the birds were provided with equal amounts of light, light intensity was measured as W/m^2 of irradiance using a radiometer, and this irradiance was converted to illuminance to ensure an average light intensity of 15 ± 0.2 lux in each chamber (Hassan *et al.*, 2016). The temperature was maintained at 31 °C from one to three days of age, and then decreased by 1 °C every two days until a temperature of 26 °C was reached. The humidity ranged from 75% to 80%. All goslings were fed the same diet, containing 11.75 MJ metabolisable energy/kg of diet and 180 g crude protein/kg of diet.

The average daily gain (ADG), average daily feed intake (ADFI), and feed/gain ratio (F/G) for one to 14 days of age, as well as the final BW (FBW) at 14 days of age, were measured on a per-pen basis. At 14 days of age, one gosling per pen was selected and blood samples were collected from the jugular vein into an anticoagulation vacuum tube. Whole blood samples were centrifuged at $3000 \times g$ for 20 min to separate the plasma, and were then stored at -70 °C until analysis. Growth hormone (GH), insulin-like growth factor 1 (IGF-1), immunoglobulin Y (IgY), and immunoglobulin M (IgM) concentrations in the plasma were measured using appropriate commercial analytical ELISA kits (Nanjing Jiancheng Bioengineering Institute, Nanjing, China). The change in absorbance at 450 nm

was monitored using a microplate reader (SpectraMAX Plus384, Molecular Devices, San Francisco, CA, USA) according to the manufacturer's instructions.

After collecting the blood samples, the goslings were slaughtered. The entire leg muscles were removed and weighed, and the *gastrocnemius* muscles (~0.3 cm × 0.3 cm × 0.6 cm in size) from the left legs were removed and fixed in 4% paraformaldehyde fixative solution. The fixed sections were processed, dehydrated, and embedded in paraffin wax, and these sections were then sliced into 5 µm transects and stained with haematoxylin-eosin. The diameter and density of the leg muscle fibres were determined using a digital camera microscope (BA210 Digital, McAudi Industrial Group Co., Ltd., Xiamen, China) and a Motic Advanced 3.2 digital image analysis system. Data were subjected to one-way analysis of variance using the general linear model procedure of SAS (SAS Institute Inc., Cary, NC, USA), with 'pen' used as the experimental unit for analysis. When differences between groups were significant ($P < 0.05$), means were compared using Duncan's multiple comparison procedure in SAS.

Results and discussion

The effects of lighting colour on the growth performance of goslings are presented in Table 1. There was no significant difference in the IBW between the groups. No significant effects on the FBW and ADG were observed; however, the goslings exposed to blue and green light had lower ADFIs and F/G ratios than those exposed to red and white light ($P < 0.05$). Some of these results agreed with those of Li *et al.* (2020), who reported that there were no statistically significant differences in the BWs of Magang geese exposed to blue, red, and white light during their early stages of growth, although a numerically higher BW was obtained for the blue light-treated geese. A study on 10-month-old (on average) Roman breeder geese similarly showed that geese reared under blue, red, and white light had comparable BWs and weight gains (Chang *et al.*, 2016).

Table 1 The effects of exposure to four different monochromatic light colours on the growth performance of 1- to 14-day-old goslings¹

	Light colour treatment groups				SEM	P-value
	Red	Blue	Green	White		
Initial BW (g/bird)	79.00	78.92	79.04	78.96	1.053	0.917
Final BW (g/bird)	571.8	586.5	586.2	594.6	11.92	0.560
ADG (g/bird/day)	35.20	36.25	36.22	36.84	0.853	0.558
ADFI (g/bird/day)	55.70 ^{ab}	53.64 ^b	54.70 ^b	58.44 ^a	1.108	0.037
F/G ratio (g/g)	1.584 ^a	1.480 ^b	1.511 ^b	1.588 ^a	0.022	0.004

¹ Each value represents the mean of six replicates. ^{a,b} Means in the same row with different superscript letters differ significantly ($P < 0.05$). SEM: standard error of the mean, BW: body weight, ADG: average daily gain, ADFI: average daily feed intake, F/G: feed/gain

Findings on the effects of lighting colours on other poultry species have been inconsistent. Cao *et al.* (2008) found that broilers reared under blue light had higher BWs than those reared under other light colours, with no significant difference in the FCRs. Ke *et al.* (2011) reported that blue LED light increased the BWs of broilers at 49 days of age. However, a field study conducted by Firouzi *et al.* (2014) found no significant differences in the BWs of broilers at 42 days of age, when these broilers were reared under blue, green, red, or yellow lights. House *et al.* (2021a,b) also observed no differences in the BW and FCR when ducks were reared under different monochromatic LED light colours or under mixed LED light colours. In contrast, Cambell *et al.* (2015) found that ducks raised under blue light had lower BWs than ducks raised under white and red light. Kim *et al.* (2014) reported that ducks exposed to blue, green, white, and red light had comparable BWs and FCRs at one to three weeks of age, but ducks exposed to green and red light had higher BWs and greater weight gain at four to six weeks of age.

In the present study, the lower FCR found for the goslings in the blue and green light groups might be due to blue and green light decreasing the movement of poultry (Sultana *et al.*, 2013). It is

worth noting that some studies have shown that ducks exposed to blue light exhibited higher levels of anxiety and stress (Cambell *et al.*, 2015; House *et al.*, 2021a). Whether and how the behaviour and stress state of geese, as a type of waterfowl, is affected by light colour requires further research.

As shown in Table 2, there were no significant differences between the different light colour groups in the leg muscle weight and leg muscle fibre diameter and density ($P > 0.05$). Studies on the effects of light colour on muscle development in geese are lacking. In ducks, previous studies have shown that green light could improve meat quality traits and muscular fatty acid composition (Kim *et al.*, 2014; Hassan *et al.*, 2016). Previous studies have also found that blue light and green light promoted muscle development in broilers. Cao *et al.* (2008) and Ke *et al.* (2011) reported that the leg muscle weights of 49-day-old broilers reared under blue light were higher than those of broilers reared under white or red light, which were similar to those of broilers exposed to green light. Pan *et al.* (2015) found that green light increased the leg weights of 78-day-old broilers, compared to white and blue light. Liu *et al.* (2024) similarly found that the *pectoralis major* and *gastrocnemius* muscle weights of broilers exposed to blue and green light were higher than those of broilers exposed to white and red light.

Muscle mass is related to both the number of muscle fibres in the muscle, and their size. Fibre size can be determined by measuring the diameter or cross-sectional area of fibres in histological cross-sections, while the total number of fibres can be determined by extrapolating the number of fibres per unit area to the entire muscle cross section (Rehfeldt *et al.*, 2004). It has been reported that green light and blue light promoted the muscle fibre development of broilers (Liu *et al.*, 2008). However, in the current study, the four treatment groups had comparable muscle fibre diameters and densities, indicating that the light colours used had limited effects on muscle development in goslings.

Table 2 The effects of exposure to four different monochromatic light colours on leg muscle development and blood parameters in 1- to 14-day-old goslings¹

	Light colour treatment groups				SEM	P-value
	Red	Blue	Green	White		
Leg muscle traits						
Total muscle weight (g)	69.55	75.12	75.96	76.30	4.334	0.633
DIA (μm)	26.76	29.50	27.71	27.83	1.511	0.587
DEN (N/mm^2)	1580	1600	1534	1328	109.1	0.179
Blood parameters						
GH (ng/mL)	2.224	2.323	2.385	2.365	0.172	0.915
IGF-1 (ng/mL)	63.41	64.09	63.35	63.11	4.718	0.998
IgY (mg/mL)	11.41	11.47	10.48	10.08	0.508	0.141
IgM (mg/mL)	1.001	1.014	0.961	0.933	0.056	0.724

¹ Each value represents the mean of six replicates. SEM: standard error of the mean, DIA: diameter of leg muscle fibres, DEN: density of leg muscle fibres, GH: growth hormone, IGF-1: insulin-like growth factor 1, IgY: immunoglobulin Y, IgM: immunoglobulin M

The effects of light colour on the blood parameters of the goslings are presented in Table 2. No significant differences between the treatment groups in the GH, IGF-1, IgY, and IgM concentrations were observed. Insulin-like growth factor 1 forms part of the hypothalamic-pituitary-somatotropic axis, is a primary mediator of the effects of GH, and has growth-promoting effects on almost every cell in animals, especially skeletal muscle cells. In our study, the lack of differences in the IGF-1 and GH concentrations were consistent with the observation that there were no significant effects on growth performance and muscle development.

Immunoglobulins play a vital role in identifying and neutralising foreign objects, such as pathogenic bacteria and viruses, and their plasma concentrations provide indicators of poultry immunity. A previous study found that broilers exposed to blue light had higher circulating levels of IgG and IgA than those exposed to white light (Hassan *et al.*, 2014). Furthermore, other previous studies have shown that monochromatic blue or green light could promote the proliferation of lymphocytes in the thymus

and bursa of Fabricius of chickens (Jian *et al.*, 2015; Chen *et al.*, 2016). However, in the current study, a positive impact of blue or green light on humoral immunity was not observed.

Conclusions

Short-term exposure to monochromatic LED light had little effect on the growth and muscle development of goslings from one to 14 days of age. However, goslings reared under blue and green light had higher feed efficiencies, and the mechanism responsible for this effect warrants further investigation. The inconsistent results in the literature for various poultry species suggest species-specific nuances in light perception, which should be considered when selecting artificial light colours for use in goose production.

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Authors' contributions

Conceptualisation: C. Wang and J.J. Xue; methodology: X.F. Huang and Z.L. Liu; experiment: J.J. Xue, Z.L. Liu, Y. Chen, H. Zhong, and Y. Luo; writing (original draft preparation): J.J. Xue and X.F. Huang; review and editing: J.J. Xue and C. Wang; supervision: C. Wang and Q. Wang. All authors have reviewed and approved the submitted version of the manuscript.

Conflict of interest declaration

The authors declare that they have no conflicts of interest.

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