

Effect of Using Different Colored LED Lights on Gonads, egg Number and Weight in Japanese Quails

Key words

LED;
light color;
quail;
reproduction

Ismail Gökce Yildirim^{1*}, Ece Koc Yildirim² Firuze Turker Yavas¹

¹Department of Anatomy, ²Department of Physiology, Faculty of Veterinary Medicine, Aydin Adnan Menderes University, Aydin 09000, Turkey

*Corresponding author: gyildirim@adu.edu.tr

Abstract: Artificial lighting plays a crucial role in regulating the maturation of the reproductive system of birds during puberty and thus affects their reproductive capacity. The aim of this study was to investigate the morphometric effects of the use of different coloured light-emitting diodes (LEDs) on the gonads of male and female Japanese quail (*Coturnix coturnix japonica*). The experimental groups were also examined with regard to egg count, weight, fertility and hatchability. A total of 240 quails of mixed sex were subjected to three different light colours, namely white, green and blue LEDs. The anatomical condition of the birds was examined at 42 days of age. To evaluate the potential effects of the different light colours on the number and weight of eggs, a cohort of 12 female and 3 male quails from each group were observed for an additional 30 days under identical experimental conditions and light exposures. An assessment was conducted to determine the differences in the number and weight of eggs between the different groups as a function of the number of days. The use of LED lights in different colours had no significant effect on the development of the testes in males and the ovaries in females. Between days 42 and 72 of the experiment, there were no discernible differences in the egg quantities of the quails, reared under different light colours. However, the eggs in the blue light group had a higher weight than those in the white light group. Ultimately, the use of white, green and blue LED lamps for photostimulation had no discernible effect on the growth of testes and ovaries, with the exception of egg weight.

Received: 3 January 2024

Accepted: 23 July 2024

Introduction

Lighting significantly influences poultry performance and exercise levels (1), affecting metabolic functions like feeding, digestion, and various physiological and behavioural processes. Birds perceive light through brain regions such as the pineal gland, pituitary gland, hypothalamus, and retina (2). Extra-retinal photoreceptors in these areas play a crucial role in regulating diverse biological processes in domestic poultry, including circadian rhythms, annual cycles, breeding behaviour, and the release of reproductive hormones (3, 4).

Research has investigated the effects of different light durations and intensities on the laying hens' reproductive processes, growth, sexual maturation, and reproductive

performance (5–7). However, there are few studies on the effects of light wavelengths on Japanese quails. The wavelength of light affects the sensitivity of birds', which are the most sensitive at a wavelength of 562 nm within the 315–750 nm range. For broilers, blue (400–480 nm) and green (545–575 nm) light stimulates growth. Green light promotes early growth; changing light conditions further accelerate growth (8, 9). Green-to-blue or green-to-green-blue lighting enhances meat quality, body, and muscle growth during female broiler rearing (10). Yet, green light exposure during embryogenesis alters weight gain and breast muscle size in male broilers without affecting meat quality or composition (11). Green-to-blue and blue-to-green light exchanges increase broiler growth and productivity

(12). Monochromatic green light during incubation stages enhances muscle growth by augmenting satellite cell quantity and diversity (13). A combination of red and green light might mimic the effects of monochromatic red light on increasing egg production in laying hens (14).

Studies in laying hens suggest different types of light-emitting diode (LED) light affect the growth (14, 15) and reproduction of the animals (16). However, the effects of different LED types on the reproductive development of quails before and after puberty have only been studied to a limited extent. The aim of this study was to investigate the effects of different light sources on morphometric measurements of testes, the number of pre-ovulatory follicles, and the number, weight, fertility, and hatchability of eggs in Japanese quails. Initially, we investigated the morphometric impact of different coloured LED lights on the reproductive organs of male and female Japanese quail (*Coturnix coturnix japonica*). Additionally, we observed the number and weight of eggs in the experimental groups under identical conditions to understand their effects on eggs and fertility.

Material and methods

Birds, Bird Facilities, and Experimental Design

The Animal Care and Use Committee of Aydin Adnan Menderes University granted ethical approval (64583101/2023/28) for the experimental procedures. The study took place at the Poultry Research Unit in Turkey, where 240 mixed-sex Japanese quail (*Coturnix coturnix japonica*) were housed in a masonry shed divided into three light-isolated rooms over a 10-week period. The initial temperature was 33 °C, gradually reducing by 3 °C weekly until reaching 23 °C, while maintaining relative humidity between 50 and 60%.

The quail chicks were kept in chick rearing cages with a size of 90 cm (width) x 45 cm (depth) x 25 cm (height), and in the same position, number of feeders and drinkers throughout the experiment. Different 9 W LED bulbs (CT-4277 CATA, Turkey) were tested in the rooms, emitting blue (480 nm), green (560 nm), and white light (400–770 nm) at an intensity of 20 lx, positioned above the cages. The photoperiod was set at 24 hours of light and 0 hours of darkness (24L:0D) throughout the experiment.

Experimental Procedure

These chicks were divided into three groups of 80 quails each—48 males and 32 females—exposed to three different LED light colours (white, green, and blue). On day 42, 60 quails were randomly selected from the replicates (5 from each cage, totaling 20 birds per group) and euthanized by decapitation. Male quail testicles (total 36) were measured for dimensions and weight, while the quantity of follicles was counted in female quails. Photos of each bird

were taken on millimetric paper and analysed using BSD-2-licensed Image J software for measurements (Figure 1). This aimed to assess the potential long-term effects of various light colours on morphometric measurements of testes and the number of pre-ovulatory follicles. Furthermore, within each group, 12 female and 3 male quails (excluding those euthanized) were observed for an additional 30 days (between 42nd and 72nd day) under the same light treatments and setup. Daily egg counts and weights were recorded during this period. Hen Day Egg Production (HDEP) has been observed between the 42nd and 72nd day of the trial. Hen day egg production is expressed in percentage (%) (Table 1). The fertilization rate of the eggs was calculated using the formula: (number of chicks hatched / number of eggs placed in the machine) x100. All eggs were incubated in the same incubator.

Statistical Analysis

SPSS 21.0 (Statistical Package for the Social Sciences for Windows, IBM Corp., Armonk, NY, US) was used to analyse the data. The Shapiro-Wilk test was used to determine whether the data were normal. The homogeneity of variances assumption was confirmed using Levene's test. Results from the post hoc Bonferroni test and one-way analysis of variance (ANOVA) test were used to determine whether the variances were homogeneous. If the variances were not homogeneous, The Welch test and the post hoc Tamhane's T2 test were used. A statistically significant result was defined as $P < 0.05$.

Results

No significant effects on the morphometric measurements of the testes and the number of pre-ovulatory follicles were observed in the three light-colored groups. In the study with male quails exposed to white, green and blue light, testicular weight, width and length were measured in different light groups (Table 1). Despite these variations in weight, width and length measurements within the light spectrum, the analysis revealed no statistically significant differences in the testicular characteristics of male quails exposed to white, green or blue light. Female quails had an average pre-ovulatory follicle numbers of 3.50 ± 0.93 for white light, 4.63 ± 0.74 for green light, and 4.00 ± 1.31 for blue light across the groups, indicating consistency (Figure 1).

Egg counts between the days 42 and 72 under white, green, and blue lights are summarized in Table 1, with no notable difference among the groups. However, egg weights varied significantly; female quails raised in blue light produced heavier eggs compared to those under white light ($P = 0.012$) (Table 1). We collected 100 eggs from each group between days 62 and 72 and placed them in the incubator to check their fertilization scores.

Table 1: Comparison of testis, egg, and fertilization values taken at different days and intervals between groups

Day 42					
Variable	Light-Emitting Diode (LED)				P
	n	White	Green	Blue	
Testis Weight (mm)	12	3.13 ± 0.80	2.94 ± 0.57	2.75 ± 0.68	0.421
Testis Width (mm)	12	14.70 ± 1.43	14.27 ± 1.53	14.02 ± 1.54	0.541
Testis Length (mm)	12	23.53 ± 2.85	22.99 ± 1.56	22.28 ± 2.02	0.387
Pre-ovulator follicles number	8	3,50 ± 0,93	4,63 ± 0,74	4,00 ± 1,31	0,111
Testis Relative Weight (%)	12	1,39±0,38	1,32±0,37	1,27±0,31	0,739
Day 42-72					
Egg weight (g)	12	11. 22 ± 0.49 ^a	11.25 ± 0.70 ^{ab}	11.61 ± 0.78 ^b	0.012
Average Daily Egg Number	12	10.00 ± 1.87	10.54 ± 1.44	10.25 ± 1.75	0.649
Hen Day Egg Production (%)	12	83,33 ± 3,17	87,85 ± 2,46	85,42 ± 2,98	0,649
Day 62-72					
Fertilization	100	%77	%79	%68	

Data are expressed as means ± SEM. ^{a, b}: Means with different superscript letters in the same column differ (*P* < 0.05)

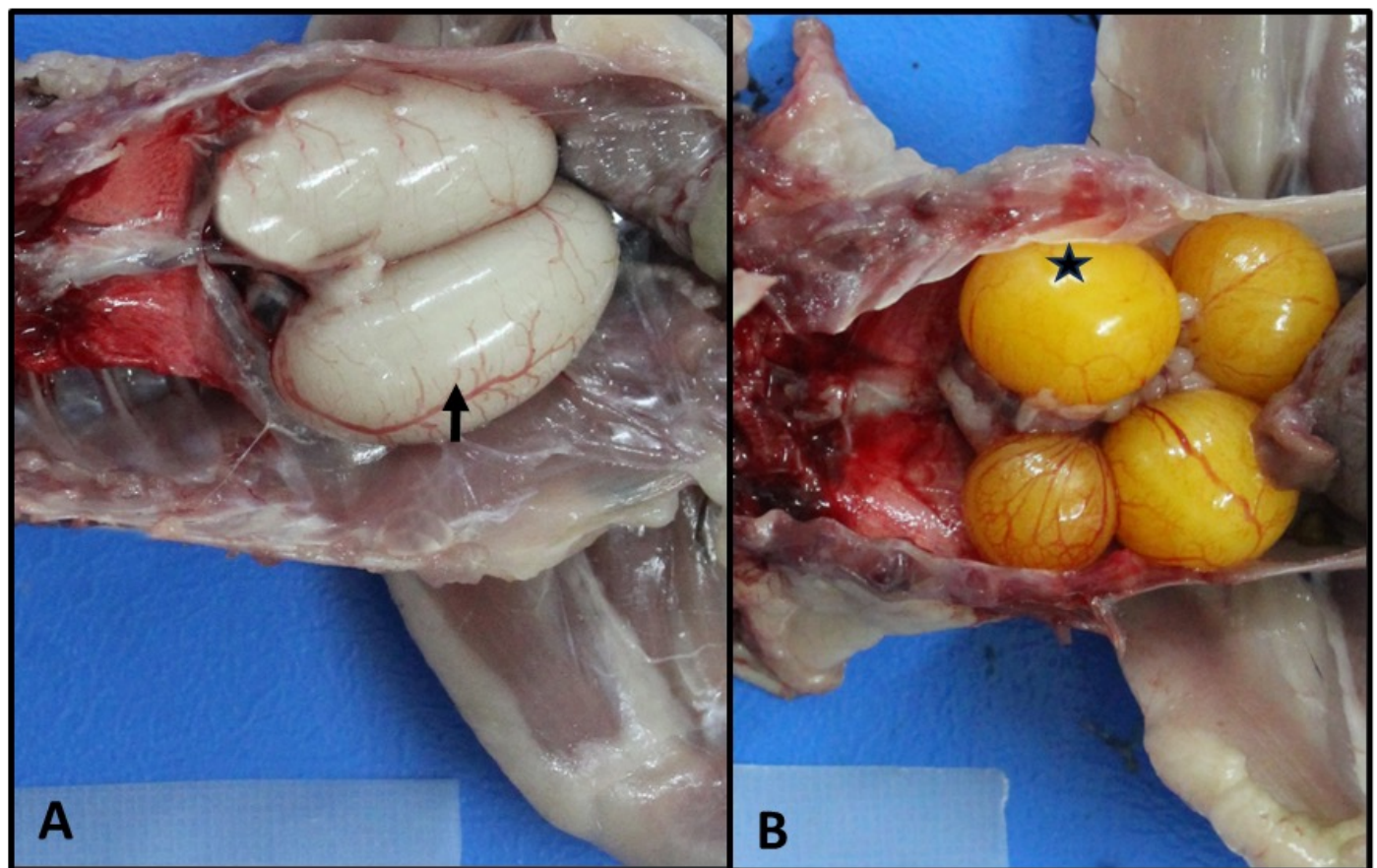


Figure 1: Representation of testicles (A) and pre-ovulatory follicles (B) with measurement paper. Black arrow; testis, black star; pre-ovulatory follicle

Upon evaluating the data, we found that out of 100 eggs in the white light group, 77 hatched. Of the remaining 23 eggs, 8 were early deaths, 6 were late embryonic deaths, and 9 were infertile eggs. For the green light, 79 chicks hatched out of 100 eggs. Of the remaining 21 eggs, 6 were early deaths, 7 were late embryonic deaths, and 8 were infertile eggs. In the blue light experiment, 68 chicks hatched from 100 eggs with 19 of the remaining 32 eggs recorded as early deaths, 4 as late embryonic deaths, and 9 as infertile eggs.

Discussion

The regulation of the hypothalamic-pituitary-gonadal axis in avian reproduction is influenced by light, activating retinal and extra-retinal photoreceptors (17). Opsin-containing photoreceptive cells, sensitive to diverse wavelengths, are the first light perceivers (18). The stimulation intensity of different wavelengths affects each photoreceptive cell individually. Shorter wavelengths like blue (400–500 nm) and green (500–600 nm) not only stimulate the retinal photoreceptors more strongly, but also suppress the reproductive axis, which affects the growth and behavior of birds (4, 17). Red light, with greater transcranial penetration (600–700 nm), primarily stimulates extra-retinal photoreceptors (4). However, the physiological effects of these wavelengths seem to vary across bird species. For instance, studies on broiler chickens show that blue and green light promotes growth (9), while red light enhances egg production in laying hens (14). In quails, exposure to green and red light appears to be beneficial for both female and male gonadal cycles (19).

Our study found no impact on the testicular weights and sizes of male quails from various light wavelengths (white, green, and blue) over 42 days. Similar findings were observed in Rete et al. (2017), where testicular weight on days 35 and 47 remained unaffected by white, green, or blue light exposure (20). However, on the day 57, quails raised in white light exhibited greater testicular weight than quails reared under blue and green light. This difference could be related to the presence of red wavelengths in white LED light, depending on the duration of exposure. Additionally, the development of the cloacal gland may have been affected, as another study found that there appears to be a significant relationship between testicular weight and cloacal gland size (21).

The number of ovaries in female quails was not affected by light of different colours in this study, which is comparable to the study of Almedia et al. (2015), in which the effects of different wavelengths (red, white, blue, green, and yellow) on the female reproductive system in Japanese quails were evaluated for 49 days (22). Ahmad et al. (2023) found no difference in the number of ovaries between white, blue, and green lights after 8 weeks (23), while Bobadilla-Mendez et al. (2016) found the most favourable results with white LED

light at the 8th week (24). Studies like Rogers et al. (2015) demonstrated the effect of white LED light on the body weight of quails during the growth phase (25). However, it is known that quails exhibit limited efficiency in responding to blue and green light (26). These differences in the ability of the light sources to influence the sexual maturity of the poultry and the onset of the laying cycle probably explain these observations (27).

The evaluation of egg weights collected daily for four weeks, starting on the day 42 of the experiment, showed that quails reared with blue light produced heavier eggs compared to those reared with white light. Su et al. (2021) compared the weight of duck eggs exposed to different lighting regimes, where hens exposed to white and red light laid smaller eggs than Brown Tsaiya ducks exposed to blue light (28). Hassan et al. (2013) reported that eggs laid under red and white light weighed similarly but were lighter than those laid under blue light (14). In contrast, Ahmad et al. (2023) found no notable variation in Japanese quail egg weight between white, blue, and green light treatments (23). However, our results suggest that stimulation with white light resulted in lighter eggs than stimulation with blue light.

Conclusion

The different light wavelengths had no effect on the gonads of the Japanese quail during the 42-day experiment. However, egg weight in the following four weeks was significantly affected by exposure to blue light. Longer-term and more comprehensive studies, including histopathologic examination of the reproductive organs and assessments of reproductive hormones, are needed to better understand the effects of different light wavelengths on reproductive activity.

Acknowledgements

We would like to thank Assistant Professor Dr. Mehmet Kaya for his help and support in experimental design and bird care.

Author Contributions. Ismail Gokce Yildirim: conceptualization, methodology, investigation, writing - original draft, project administration. Ece Koc Yildirim: writing, investigation. firuze Turker Yavas: investigation, formal analysis.

Author Declarations. The authors declare no conflict of interest.

References

1. Zhao RX, Cai CH, Wang P, et al. Effect of night light regimen on growth performance, antioxidant status and health of broiler chickens from 1 to 21 days of age. *Asian-Austral J Anim Sci* 2019; 32(6): 904–11. doi: 10.5713/ajas.18.0525
2. Kuenzel WJ, Kang SW, Zhou ZJ. Exploring avian deep-brain photoreceptors and their role in activating the neuroendocrine regulation of gonadal development. *Poult Sci* 2015; 94(4): 786–98. doi: 10.3382/ps.2014-4370
3. Yoshimura T, Yasuo S, Watanabe M, et al. Light-induced hormone conversion of T4 to T3 regulates photoperiodic response of gonads in birds. *Nature* 2003; 426(6963): 178–81. doi: 10.1038/nature02117
4. Mobarkey N, Avital N, Heiblum R, et al. The role of retinal and extra-retinal photostimulation in reproductive activity in broiler breeder hens. *Domest Anim Endocrinol* 2010; 38(4): 235–43. doi: 10.1016/j.domaniend.2009.11.002
5. Renema RA, Robinson FE. Effects of light intensity from photostimulation in four strains of commercial egg layers: 1. Ovarian morphology and carcass parameters. *Poult Sci* 2001; 80(8): 1112–20. doi: 10.1093/ps/80.8.1112
6. Chen H, Huang RL, Zhang HX, et al. Effects of photoperiod on ovarian morphology and carcass traits at sexual maturity in pullets. *Poult Sci* 2007; 86(5): 917–20. doi: 10.1093/ps/86.5.917
7. Robinson FE, Renema RA, Bouvier L, et al. Effects of photostimulatory lighting and feed allocation in female broiler breeders 1. Reproductive development. *Can J Anim Sci* 1998; 78(4): 603–13. doi: 10.4141/A98-017
8. Rozenboim I, Biran I, Uni Z, et al. The effect of monochromatic light on broiler growth and development. *Poult Sci* 1999; 78(1): 135–8. doi: 10.1093/ps/78.1.135
9. Rozenboim I, Biran I, Chaiseha Y, et al. The effect of a green and blue monochromatic light combination on broiler growth and development. *Poult Sci* 2004; 83(5): 842–45. doi: 10.1093/ps/83.5.842
10. Karakaya M, Parlat SS, Yilmaz MT, et al. Growth performance and quality properties of meat from broiler chickens reared under different monochromatic light sources. *Br Poult Sci* 2009; 50(1): 76–82. doi: 10.1080/00071660802629571
11. Zhang L, Zhang HJ, Qiao X, et al. Effect of monochromatic light stimuli during embryogenesis on muscular growth, chemical composition, and meat quality of breast muscle in male broilers. *Poult Sci* 2012; 91(4): 1026–31. doi:10.3382/ps.2011-01899
12. Cao J, Wang Z, Dong Y, et al. Effect of combinations of monochromatic lights on growth and productive performance of broilers. *Poult Sci* 2012; 91(12): 3013–8. doi: 10.3382/ps.2012-02413
13. Zhang L, Zhang HJ, Wang J, et al. Stimulation with monochromatic green light during incubation alters satellite cell mitotic activity and gene expression in relation to embryonic and posthatch muscle growth of broiler chickens. *Animal* 2014; 8(1): 86–93. doi: 10.1017/S1751731113001882
14. Hassan MR, Sultana S, Choe HS, et al. Effect of monochromatic and combined light colour on performance, blood parameters, ovarian morphology and reproductive hormones in laying hens. *Ital J Anim Sci* 2013; 12: e56, 359–64.
15. Hassan MR, Sultana S, Choe HS, et al. Effect of combinations of monochromatic LED light color on the performance and behavior of laying hens. *Poult Sci J* 2014; 51(3): 321–6. doi: 10.2141/jpsa.0130105
16. Liu L, Li D, Gilbert ER, et al. Effect of monochromatic light on expression of estrogen receptor (ER) and progesterone receptor (PR) in ovarian follicles of chicken. *PloS One* 2015; 10(12): e0144102. doi: 10.1371/journal.pone.0144102
17. Tsutsui K, Bentley GE, Bedecarrats G, Osugi T, Ubuka T, Kriegsfeld LJ. Gonadotropin-inhibitory hormone (GnIH) and its control of central and peripheral reproductive function. *Front Neuroendocrinol* 2010; 31(3): 284–95. doi: 10.1016/j.yfrne.2010.03.001
18. Parvin R, Mushtaq M, Kim M, et al. Light emitting diode (LED) as a source of monochromatic light: a novel lighting approach for behaviour, physiology and welfare of poultry. *Worlds Poult Sci J* 2014; 70: 543–56. doi: 10.1017/S0043933914000592
19. Oishi T, Lauber JK. Photoreception in the photosexual response of quail. II. Effects of intensity and wavelength. *Am J Physiol* 1973; 225(4): 880–6. doi: 10.1152/ajplegacy.1973.225.4.880
20. Retes PL, Espósito M, das Neves DG, et al. Influence of different types of lamps on the reproductive development of male Japanese quail (*Coturnix coturnix japonica*). *Theriogenology* 2017; 94: 59–3. doi: 10.1016/j.theriogenology.2017.02.011
21. Biswas A, Mohan J, Sastry KV, et al. Effect of dietary Vitamin E on the cloacal gland, foam and semen characteristics of male Japanese quail. *Theriogenology* 2007; 67(2): 259–63. doi: 10.1016/j.theriogenology.2006.07.010
22. Almedia AZ, Jacome IMTD, Tavares RA, et al. Effect of Different LED Light Colors on Development of the Reproductive System of Quails. *Int J Poult Sci* 2015; 14(7): 383–6. doi: 10.3923/ijps.2015.383.386
23. Ahmad F, Sharif M, Ashraf M, et al. Effect of different light intensities and colors on growth performance and reproductive characteristics in Japanese quails. *Turkish J Vet Anim Sci* 2023; 47(3): 185–93. doi: 10.55730/1300-0128.4285
24. Bobadilla-Mendez MF, Rojas-Granados CP, Andrade EF, et al. Effect of different light sources on reproductive anatomy and physiology of Japanese quail (*Coturnix coturnix japonica*). *Anim Reprod Sci* 2016; 168: 50–6. doi: 10.1016/j.anireprosci.2016.02.025
25. Rogers AG, Pritchett EM, Alphin RL, et al. I. Evaluation of the impact of alternative light technology on male broiler chicken growth, feed conversion, and allometric characteristics. *Poult Sci* 2015; 94(3): 408–14. doi: 10.3382/ps/peu045
26. Woodard AE, Moore JA, Wilson WO. Effect of wave length of light on growth and reproduction in Japanese quail (*Coturnix coturnix japonica*). *Poult Sci* 1969; 48(1): 118–23. doi: 10.3382/ps.0480118
27. Baxter M, Joseph N, Osborne VR, et al. Red light is necessary to activate the reproductive axis in chickens independently of the retina of the eye. *Poult Sci* 2104; 93(5): 1289–97. doi: 10.3382/ps.2013-03799
28. Su CH, Cheng CH, Lin JH, et al. The effect of different colored light emitting diode illumination on egg laying performance, egg qualities, blood hormone levels and behavior patterns in Brown Tsaiya duck. *Animal Biosci* 2021; 34(11): 1870–8. doi: 10.5713/ab.20.0657

Vpliv barve led-svetlobe in gostote živali na nekatere hematološke parametre in oksidativni stres pri japonskih prepelica

I. G. Yildirim, E. K. Yildirim, F. T. Yavas

Izvleček: Študija je ocenjevala učinke barve svetlobe svetlečih diod (LED) in gostote naselitve na hematološke parametre, oksidativno presnovo in težo organov prepelic. Več ključnih dejavnikov upravljanja, ki vplivajo na dobro počutje brojlerjev, vključuje barvo svetlobe in gostoto naselitve. Zato je bil namen te študije ugotoviti učinek različnih barv svetlobe in gostote naselitve na hematološke parametre in parametre oksidativnega stresa pri japonskih prepelica. V ta namen so bile pri prepelica, ki so bile izpostavljene različnim barvam svetlobe in gostoti naselitve, izmerjene ravni malondialdehida (MDA), superoksid dismutaze (SOD), katalaze (CAT) in glutationa (GSH) z uporabo komercialno dostopnih kompletov ELISA. V študiji je bilo 720 enodnevnih japonskih prepelic (*Coturnix coturnix japonica*) naključno razvrščenih v eno od šestih obravnav, vsaka s štirimi dvojniki po 30 ptic. Poskus je bil zasnovan kot faktorska razporeditev obdelav 3 x 2 s tremi barvami LED-svetlobe (bela, modra in zelena) in dvema gostotama naselitve (nizka = 200 cm²/ptico; visoka = 100 cm²/ptico). Pri starosti 42 dni je bilo naključno izbranih 20 prepelic iz vsake skupine za analizo nekaterih hematoloških parametrov. Glede na dobljene rezultate je bilo razmerje med heterofilci in limfociti (H/L) znatno višje pri prepelica, izpostavljenih beli LED-svetlobi, vendar vpliv gostote naselitve na razmerje H/L ni bil značilen. Na indikator oksidativnega stresa MDA barva svetlobe ni vplivala, je pa visoka gostota naselitve drastično zmanjšala aktivnosti CAT in GSH v jetrih. Teža srca je bila manjša pri prepelica, ki so bile izpostavljene modri LED-svetlobi. Gostota naselitve ni vplivala na maso srca in jeter. Zaključimo lahko, da bela LED-svetloba sicer poveča razmerje H/L in stresne razmere, vendar ne vpliva na kazalnike oksidativnega stresa. Te ugotovitve so poudarile potrebo po določitvi optimalnih barv LED-svetlobe za prepelice v komercialnih proizvodnih okoljih, da bi povečali dobrobit jate. Za razumevanje učinkov in iskanje najboljše barve LED-svetlobe za prepelice pri različnih gostotah naselitve je potrebnih več raziskav.

Ključne besede: prepelice, LED-svetloba, razmerje med heterofilci in limfociti, oksidativni stres, gostota naselitve