The effect of monochromatic, combined, and mixed light-emitting diode light regimes on growth traits, fear responses and slaughter-carcass characteristics in broiler chickens

Yunus Sayin
Akdeniz Üniversitesi: Akdeniz Universitesi
Onur Kaplan
Akdeniz University: Akdeniz Universitesi
Esra Karaduman
Akdeniz University: Akdeniz Universitesi
Dost Mohammad Haqyar
Akdeniz University: Akdeniz Universitesi
Doğan Narinç (dnarinc@akdeniz.edu.tr)
Akdeniz University: Akdeniz Universitesi https://orcid.org/0000-0001-8844-4412

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Abstract

This study aims to determine the effects of blue and green monochromatic, blue-green combination, and blue-green mixed led lighting systems on growth, fear, and carcass characteristics of broilers reared in an extensive indoor system. Experimental groups were formed as follows; 1-conventional (incandescent), 2-blue, 3-green, 4-blue-green combined (blue for the first ten days, then green), 5-green-blue combined (green for the first ten days, then blue), and 6-blue-green intermittent (alternating every 5 minutes) monochromatic lightings. It was detected that the average values of the body weight of chickens at 42 and 56 days of age in the green-blue group were higher than those of the other treatment groups (both $P<0.05$). It was determined that the broilers in the green and green-blue groups had higher means of the β_0 parameter of Gompertz model. The tonic immobility, emergence test, home cage avoidance test, a looming human test, and box-plus experimenter test were applied to determine the fear responses. It was determined that the worst results for fear responses of broilers were in the intermittent lighting group and green-blue combined group. As a result, it was determined that the application of green monochromatic lighting in the first ten days of the fattening period and blue monochromatic lighting in the following period positively affected growth and slaughter-carcass characteristics. However, it was found that broilers reared under green-blue combined lighting had high fear levels.

Introduction

Birds have highly specialized visual systems and more types of cones than mammals. The light is received by receptors and transmitted to the hypothalamus in chickens. The stimulation of the hypothalamus varies depending on the wavelength of light. Thus, the physiological events caused by different wavelengths also differ (Prescott et al., 2003; Kram et al., 2010; Yang et al., 2018). In recent years, different artificial lighting programs have been widely used to increase the productive performance of broilers. The light supplement's source, spectrum, and intensity are important environmental factors in modern broiler management (Zhang et al., 2012). In recent years, the energy-efficient, narrowband emission of light-emitting diode (led) sources makes lighting technology valuable in poultry.

Halevy et al. (1998) reported that blue and green light accelerated the development of chicks. Researchers stated that because of the decrease in the wavelength of light, muscle satellite cells (new cells) multiply faster. Fernandes et al. (2018) reported that the muscle fiber diameters of broilers treated with blue monochromatic illumination were higher than those illuminated with green and red. Many previous studies have focused on the effect of light spectrum on the growth performance in broilers. Broilers reared under green or blue light showed significantly more body weight gain and greater muscle growth than birds reared under other light spectra (Rozenboim et al., 1999; Cao et al., 2008). While some studies have reported that broilers lighted with blue and green colors have better feed efficiency and higher body weight gain (Rozenboim et al., 1999; Rozenboim et al., 2004a; Bayraktar and Altan, 2005; Olanrewaju et al., 2006), it has been reported that colors close to infrared wavelength have positive effects on reproductive and behavioral characteristics by some researchers (Gongruttananun, 2012; Sen et al., 2012; Huber-Eicher et al., 2013). Solangi et al. (2004) reported that the frequency of aggression and fighting behaviors in broilers reared under blue light was lower than those lighted with white and red light. Xie et al. (2008) lighted broilers with red, green, blue, and white led bulbs. Researchers have reported that illumination with blue light has a stress-reducing effect (Xie et al., 2008). Sultana et al. (2013) investigated the effects of different colored LED lighting on some behavioral and welfare characteristics of ducks. Researchers reported that ducks illuminated with blue and green LEDs had lower tonic immobility duration.

It is known that the number of opsin cells in the eye that detects green light is higher after hatching and that the number of opsin cells that detect blue light is higher after the first 7–10 days of age (Rozenboim et al., 2003). Green light accelerates broiler muscle growth during the early stage, whereas blue light stimulates growth in the later stage (Rozenboim et al., 1999, 2004a; Cao et al., 2008). Some researchers have also focused on the combination or mixed-use of light wavelengths based on the differences in the development of opsin cells in the retina (Rozenboim et al., 2003; Guevera et al., 2015; Olanrewaju et al., 2006). Further research found when broilers were reared under green and blue monochromatic light combinations or green and blue mixed lighting systems, their body weight, and meat quality were better than those in white (Rozenboim et al., 2004b; Karakaya et al., 2009). Cao et al. (2008, 2012) reported that green monochromatic lighting promotes the growth and development of broilers during the early stage (up to 26 days old) and that blue enhances growth during the later stage (between the ages of 27 and 49 days), in addition, blue-green and green-blue combinations had positive effects. The aim of this study is to determine the effects of blue and green monochromatic, blue-green combination, and blue-green mixed led lighting systems on growth traits, fear responses, and slaughter-carcass characteristics of broilers reared in an extensive indoor system.

Materials And Methods

The study was carried out at Akdeniz University (Antalya-Turkey) and with the decision of the Animal Experiments Local Ethics Committee of Akdeniz University, dated 18.10.2019 and numbered 128. The animal material of the study consisted of 300 one-day-old Ross 308 broiler chickens purchased from a commercial company. In the experiment, the principles of SCAHAW (Scientific Committee on Animal Health and Animal Welfare) for the extensive indoor broiler production system were applied. Six experimental groups were formed, with 50 chickens in each group, at a stocking density of 8.33 chickens/m^2. Wing numbers were assigned to all chicks at the beginning of the experiment, and body weights were weighed individually every week with a digital scale with a precision of 0.01. Experimental groups were formed as follows; 1-conventional lighting (incandescent white bulb: C), 2-blue monochromatic lighting (480 nm: B), 3-green monochromatic lighting (560 nm: G), 4-blue-green combined monochromatic lighting (blue for the first ten days, then green: BG), 5-green-blue combined monochromatic lighting (green for the first ten days, then blue: GB), and 6-blue-green mixed lighting (alternating every 5 minutes: MBG). Chicks were randomly housed in 6 light-controlled floor pens, and LED bulbs were mounted at a suitable height to provide homogeneous lighting inside the pens, and it is ensured that there is no different light or reflection for all pens. The room temperature was maintained at

32°C for the first week and then reduced by 1°C every 2 days until it reached 24°C on day 23, which was maintained until the end of the experiment. The mean RH was 60 to 65% and was kept constant within this range throughout the experiment. Chicks were fed ad libitum a starter feed containing 21.5% CP and 11.93 kcal/kg of ME (1–21. days), while a grower feed containing 19.0% CP and 11.93 MJ/kg of ME was used between the 21st and slaughter days (Narinç et al., 2015).

Wing bands were attached to all hatched chicks and after the chicks had dried, their individual live weights were measured. To obtain the estimates of individual growth curve parameters, all birds were weighed weekly from hatching to 8 weeks of age. The Gompertz nonlinear regression model (1) was used to estimate the growth curve of each chick.

$$y_t = \beta_0 e^{\left(-\beta_1 e^{-\beta_2 t}\right)} \quad (1)$$

Where yt is the weight at age t, β_0 is the asymptotic (mature) weight parameter, β_1 is the scaling parameter (constant of integration), and β_2 is the instantaneous growth rate (per day) parameter (Narinç and Genç, 2021). Parameter estimations were performed by the NLIN procedure of SAS 9.3 software (SAS Institute Inc., Cary, NC). The Gompertz model is characterized by an inflection point in a manner such that β_0/e of the total growth occurs before it and the remainder occurs after (Alkan et al., 2012). The coordinates of the point of inflection, weight (2), and time (3) at the inflection point (IPW) were obtained as follows (Narinc et al., 2017).

$$IPW = \beta_0 / e \quad (2)$$

$$IPT = ln(\beta_1)/\beta_2 \quad (3)$$

The tonic immobility durations were measured to determine the fear responses of 10 chickens randomly selected from the experimental groups every week. For the application of the tonic immobility test, the expert operator laid the bird on its back on a special device with its head hanging down. The operator placed one hand on the chicken's chest gently and without pressure, and waited for 10 seconds for the animal to immobilize. At the end of 10 seconds, the operator took his hand slowly and measured the immobility time of the bird with a stopwatch. In the measurement of the inactivity time, the maximum value was determined as 300 seconds (Campo and Davilla, 2002). The emergence test was applied to determine the fear status of 10 chickens randomly selected from the experimental groups every week. During the implementation of this test, a box with three closed sides and one open side was used. The broiler to be tested was placed in this box, and the movements of the animal in the box were observed inconspicuously, and the evaluation was made according to the time the broiler left the box. If the bird recessed to go out, it was considered passive, and if it came out in a short time, it was considered active (Jones 1987). When the broilers were 42 and 56 days old, home cage avoidance tests were applied twice a day using 10 randomly selected birds from each group. During the test, the reactions of the broiler to people and objects were measured. The operator applying the test came in front of the application cage and brought an object (colored stick) towards the animal, and the evaluation was made according to the reaction of the bird. The evaluation was made according to the following reactions of the bird: if it stands calmly without making any reaction, it is unresponsive (code:0), if it runs to the other end of the cage, it is recessive or cowardly (code:1), if it approaches the human and tries to examine the object it has extended, it is evaluated as curious and active (code:2) (Jones., 1995). Another test applied to determine the fear status of birds is the box plus experimenter test. This test was carried out by using 10 chickens randomly selected from the experimental groups each week. In the box plus experimenter test, the reaction of broilers to a human standing behind a net was measured. In the test, avoidance (code: 1), examination (code: 2), and fear (code: 3) situations were evaluated according to the approach or distance of broiler chickens (Jones, 1993). Similarly, the looming human test was applied to measure fear behaviors for 10 randomly selected broiler chickens from each group on a weekly basis Jones et al. (1981). To measure the reactions of broilers, an observer entered the cage with a camera and recorded a video by walking slowly from one end of the chamber to the other between the broilers on the ground. Evaluation is also made according to the number of animals remaining close to the observer (Jones et al., 1981).

At 8 weeks of age, the body weights of all broiler chicks were determined 8 hours after feed withdrawal and slaughtered in an experimental processing plant. The birds were manually cut, bled out, scalded (55°C, 2 min), defeathered with equipment, manually eviscerated, and the abdominal fat pad (from the proventriculus surrounding the gizzard down to the cloaca) was taken, chilled in an ice-water tank, and drained. The next day, after carcass dissection, the breast with bone and the remaining abdominal fat on cold carcasses were weighed using an electronic digital balance with a sensitivity of 0.01 g. Slaughter and dissection were performed by the same experienced operators. Cold carcass, breast, leg, wing, and total fat pad yields were calculated in relation to body weight at 8 weeks of age (Narinc et al., 2014).

To test the difference between experimental groups in terms of performance traits in chickens, the analyses of variance were applied using the SAS 9.3 GLM procedure (SAS Institute 2009). Treatment means were separated using Duncan's multiple range test. The significance level was $P < 0.05$ for comparing the means. The Rank transformation was used for the nonnormally distributed data. A generalized linear mixed-effects model with the logit function was used in the statistical analysis of the binomial or ordinal data of mortality and behavior traits in the experimental groups, and the differences between the groups were analyzed by the Tukey-Kramer method using the SAS 9.3 GLIMMIX procedure (SAS Institute 2009; Sabuncuoğlu et al., 2018).

Results

The general mean of mortality was found to be 4.33% for all experimental groups. The mean values of mortality of C, B, G, BG, GB, and MBG groups were 2%, 6%, 8%, 0%, 8%, 2%, respectively (not presented in a table). No statistically significant difference was found between the experimental groups in terms of mortality ($P > 0.05$).

The mean values of weekly body weights and Gompertz growth model parameters of broilers in experimental groups, and statistical analysis results are presented in Table 1. In terms of body weights of the broilers at 42 and 56 days of age in the experimental groups, it was determined that the average values of body weight of the chickens in the group GB in which green monochromatic lighting was applied for the first ten days and then blue was higher than the mean values of the other groups (both $P < 0.05$). The highest mean values for the mature weight parameter and inflection point weight of the Gompertz growth model were found in the G and GB experimental groups ($P < 0.05$). There were no statistical differences between the groups in terms of other parameters of the growth model. The growth curves of broiler chickens in the experimental groups obtained by the Gompertz model are presented in Fig. 1.

Table 1
The mean values of weekly body weights and Gompertz model parameters of broilers in experimental groups, and statistical analysis results

Group	**BW 42**	**BW 56**	**β_0**	**β_1**	**β_2**	**IPW**	**IPT**
C	2126.39^{d}	3320.47^{c}	6737.79^{c}	5.24	0.036	2479.63^{c}	45.60
B	2206.25^{c}	3347.93^{c}	6973.45^{b}	5.85	0.039	2568.46^{b}	45.57
G	2234.84^{b}	3446.70^{b}	7174.42^{a}	5.09	0.038	2644.21^{a}	43.02
BG	2232.07^{b}	3354.87^{c}	6797.61^{c}	5.26	0.033	2492.73^{c}	50.23
GB	2282.86^{a}	3522.19^{a}	7149.82^{a}	5.11	0.035	2634.22^{a}	46.81
MBG	2237.77^{b}	3427.62^{b}	6809.26^{c}	5.30	0.036	2511.45^{c}	46.35
SE	16.55	27.49	31.24	0.46	0.001	12.12	1.74
P Value	0.023	0.000	0.000	0.128	0.554	0.000	0.224

The statistical significance level was $P = 0.05$ and Duncan was used as a multiple comparison test. There is a statistically significant difference between the means with different letters in the same column ($P < 0.05$). The parameter β_0 represents the asymptotic weight, β_1 represents the integration coefficient, and β_2 represents the instantaneous growth rate, BNA: inflection point weight; BNY: inflection point age.

The average values of the tonic immobility duration of the broiler chickens in the experimental groups in the study and statistical analysis results are presented in Table 2. While the highest mean value of tonic immobility duration was found in the MBG group, the mean values of the chickens in the B, G, and BG experimental groups were the lowest. The mean values of the percentage of animals moving away in a looming human test performed in the study and statistical analysis results are presented in Table 3. Among the experimental groups, the highest mean value (45.31%) was measured in the group with mixed monochromatic lighting, while the lowest average value (25.69%) was found in the blue monochromatic lighting group ($P < 0.05$). The average values of the inactive duration of birds and the percentages of active birds in the emergence test and statistical analysis results are presented in Table 4. In the home cage avoidance test, the average values of the percentages obtained as a result of the classification of animals as passive, active, and cowardly, and statistical analysis results are presented in Table 5. The mean values of the percentages of the box plus the experimenter test and the statistical analysis results are presented in Table 6.

Table 2

The average values of the tonic immobility durations of the broiler chickens in the experimental groups in the study, and statistical analysis results

Group	Tonic Immobility Duration (sec.)
C	159.08[b]
B	105.39[c]
G	132.13[c]
BG	129.08[c]
GB	151.57[b]
MBG	182.22[a]
SE	6.414
P Value	0.020

The statistical significance level was P = 0.05 and Duncan was used as a multiple comparison test. There is a statistically significant difference between the means with different letters in the same column (P < 0.05).

Table 3

The average values of a looming human test results of the broiler chickens in the experimental groups in the study, and statistical analysis results

Group	Percentage of Animals Moving Away (%)
C	36.61[c]
B	25.69[d]
G	34.04[c]
BG	34.47[c]
GB	41.51[b]
MBG	45.31[a]
SE	1.09
P Value	0.000

The statistical significance level was P = 0.05 and Tukey-Kramer was used as a multiple comparison test. There is a statistically significant difference between the means with different letters in the same column ($P < 0.05$).

Table 4

The average values of the emergence test results of the broiler chickens in the experimental groups in the study, and statistical analysis results

Group	Passive time (sec)	Percentage of Active Birds (%)
C	85.70	46.25
B	94.08	40.00
G	86.41	52.50
BG	74.42	40.00
GB	75.92	40.00
MBG	79.54	43.75
SE	4.38	2.35
P Value	0.790	0.543

The statistical significance level was P = 0.05 and Tukey-Kramer was used as a multiple comparison test. There is a statistically significant difference between the means with different letters in the same column ($P < 0.05$).

Table 5
The average values of the home cage avoidance test results of the broiler chickens in the experimental groups in the study, and statistical analysis results

Group	Percentage of Passive Birds (%)	Percentage of Cowardly Birds (%)	Percentage of Active Birds (%)
C	22.50^{e}	37.50^{a}	37.50^{a}
B	70.00^{a}	20.00^{b}	10.00^{c}
G	33.75^{d}	41.25^{a}	25.00^{b}
BG	50.00^{b}	45.00^{a}	6.25^{c}
GB	38.75^{c}	36.25^{a}	25.00^{b}
MBG	23.75^{e}	43.75^{a}	32.50^{a}
SE	2.12	2.20	2.00
P Value	0.000	0.014	0.000
The statistical significance level was P = 0.05 and Tukey-Kramer was used as a multiple comparison test. There is a statistically significant difference between the means with different letters in the same column (P < 0.05).			

Table 6
The average values of the box plus experimenter test results of the broiler chickens in the experimental groups in the study, and statistical analysis results

Group	Avoiding (%)	Examining (%)	Fear (%)
C	10.00	0.00	0.00
B	0.00	0.00	0.00
G	10.00	10.00	0.00
BG	0.00	0.00	0.00
GB	0.00	10.00	0.00
MBG	0.00	10.00	0.00
SE	0.02	0.03	-
P Value	0.555	0.700	-
The statistical significance level was P = 0.05 and Tukey-Kramer was used as a multiple comparison test. There is a statistically significant difference between the means with different letters in the same column (P < 0.05).			

The mean values of cold carcass weight, cold carcass yield, and weights of carcass parts of broiler chickens in the experimental groups and statistical analysis results are presented in Table 7. While the differences between the experimental groups in terms of cold carcass yields were not statistically significant, the average value of slaughter weight of chickens in the BG experimental group was found to be higher than those of the other groups ($P < 0.05$). Similar to the cold carcass weight feature, the mean values of weights of breast and back-neck in chickens in the GB experimental group were found to be the highest ($P < 0.05$).

Table 7
The mean values of cold carcass (weight and yield), and weights of carcass parts by experimental groups and statistical analysis results

Group	Cold Carcass (g)	Cold Carcass (%)	Breast (g)	Leg (g)	Wing (g)	Back-Neck (g)
C	2762^{c}	79.64	1011^{bc}	793	248	715^{b}
B	2597^{d}	77.88	965^{c}	758	266	618^{d}
G	2751^{b}	79.18	1086^{b}	809	251	625^{d}
BG	2788^{b}	80.95	1072^{b}	822	262	688^{c}
GB	3053^{a}	78.52	1175^{a}	853	286	776^{a}
MBG	2820^{b}	79.16	1061^{b}	804	269	678^{c}
SE	53.82	1.27	24.46	16.9	5.99	13.91
P Value	0.021	0.344	0.016	0.089	0.158	0.012

The statistical significance level was $P = 0.05$ and Duncan was used as a multiple comparison test. There is a statistically significant difference between the means with different letters in the same column ($P < 0.05$).

Discussion

Similar to our results, Rozenboim et al. (2004a) reported that on the tenth day of the experiment in which they applied monochromatic lighting, the body weight averages of the broilers, which were switched from green to blue, were higher than the averages of the other experimental groups on the 46th day. In this study, the fact that the GB group had a higher body weight average than the other single, combined, and mixed groups were determined by Rozenboim et al. (2004a), Guevera et al. (2015), and Olanrewaju et al. (2016) was found to be consistent with the results reported. Rozenboim et al. (2004a) reported that the live weight averages of the chickens, which were applied to a monochromatic lighting program with a transition from green to blue on the tenth day of the experiment were higher than the averages of the other experimental groups at 46 days of age. In this study, the fact that the average values of body weight of the GB group had higher than the other single, combined, and mixed groups were found to be consistent with the results reported by Rozenboim et al. (2004a), Guevera et al. (2015) and Olanrewaju et al. (2016).

In a study carried out by Karadavut et al. (2017), growth samples of Japanese quails treated with white, red, green, yellow monochromatic lighting were analyzed with Gompertz, Broody, and Von Bertalanffy nonlinear regression models. According to the goodness-of-fit criteria, the Gompertz growth model was found to be the best-fitted model, but estimation values of model parameters were not presented in their study (Karadavut et al. (2017). Moreover, to our knowledge, there is no study in the literature on the effects of monochromatic lighting applications on the growth curve parameters of broiler chickens. While the average values (6797.61-7174.42 g) of estimations of β_0 parameters for treatment groups in this study were higher than the mean values of β_0 parameters (5453.80-6282.35 g) reported by Topal and Bölükbaşı (2008), who analyzed the growth samples of female and male broiler chickens using the Gompertz growth model. In addition, the mean values of β_1 parameters (5.09–5.85) were found to be similar to the β_1 averages (4.91–5.31) reported by Topal and Bölükbaşı (2008). Demuner et al. (2017) who modeled the growth samples of Ross, Cobb, and Hubbard broiler genotypes up to 56 days of age with the Gompertz function, reported that the mean values of the β0 parameter were between 6401–7009 g, similar to the results of this study. Analyzing the growth data of commercial chickens raised in an alternative system up to 56 days of age with the Gompertz model, Marcato et al. (2008) reported that the mean values of the β_0 parameter for Ross and Cobb genotypes were 6627.84 g and 6812.30 g, respectively.

According to the results of this study, it was determined that the broiler chickens in the G and GB groups had higher mean values of mature weight parameter, and similarly mean values of the weight of inflection point in the G and GB groups were higher. The mean values of body weights of the broilers at 42 and 56 days of age treated with continuous green monochromatic lighting were lower than those of the GB group ($P < 0.05$). However, there is no difference between the averages of the G and GB groups in terms of the mature weight parameter of the Gompertz growth curve. It is thought that this surprising situation arises because the green light applied in the G group after the inflection point suppresses the growth.

Sultana et al. (2013a) conducted a study investigating the effects of blue, green, yellow, and white monochromatic lighting on behavior traits and fear responses in ducks. They reported that ducks treated with yellow and white lighting had higher tonic immobility durations than those blue and green monochromatic lighting groups. In a study conducted by Sultana et al. (2013b), it was determined that chickens raised under red LED light had longer tonic immobility times. In that study, it was determined that there was no difference between the tonic immobility duration of chickens in the green LED group and the control groups with incandescent bulbs. In addition, it has been reported that blue monochromatic lighting reduces the tonic immobility duration. Researchers suggested that a light wavelength in the range of 440–570 nm would reduce fear responses in chickens (Sultana et al., 2013b).

Mohamed et al. (2016) also reported that mulard ducks reared with white and red lighting had longer tonic immobility durations than those reared with green and blue lighting. Researchers stated that ducks illuminated with green and blue monochromatic lights had lower fear levels. Mohamed et al. (2017) investigated the effect of monochromatic lighting on the fear level of broiler chickens, reported that the fear level of chickens with green and blue monochromatic lighting was lower.

In this study, when the effects of different monochromatic lighting applications on the fear level of broilers were examined (Table 2), it was determined that the highest average of tonic immobility time (182.22 sec) was in the BG group ($P < 0.05$). The mean values of duration of tonic immobility in broilers treated with continuous blue, continuous green, and blue-green alternating monochromatic lighting were found to be lower than those of the other groups ($P < 0.05$). These results were consistent findings with the for ducks and broilers by Sultana et al. (2013a, b), Mohamed et al. (2016, 2017). The shorter tonic immobility period of broilers reared under blue and green light may be due to the calming effect of these light colors (Prayitno et al. 1997), and birds become less active and less aggressive under these conditions (Mohamed et al. 2016). In the study, the highest mean value of tonic immobility duration was measured in broilers that were exposed to intermittent blue-green light every five minutes. It is thought that the application of intermittent lighting causes fear and anxiety in birds.

In birds, high levels of fear of humans cause a decrease in egg production, worsening in growth and feed efficiency, adversely affecting product quality and decreasing reproductive activities as well as increasing aggression, coping difficulties, and suppression of the immune system (Barnett et al, 1993; Gross and Siegel 1982; Jones 1996). Visual or physical contact with humans may cause behavioral inhibition, withdrawal, panic, and violent escape reactions in chickens as a result of adrenal responses, and in some cases, injury and deformation may occur (Jones 1996). Fear reactions, such as panic or violent escape attempts, not only waste energy and therefore incur a metabolic cost, but can also cause death in birds due to squatting and entrapment (Waiblinger et al., 2006).

In the emergence test, the mean values of passive duration of broiler chickens in different experimental groups varied between 74.42 seconds and 94.08 seconds, and there was no statistical difference between the groups ($P > 0.05$). Similarly, the application of different monochromatic lighting did not affect the percentage of active birds, and the ratios of active animals varied between 40.00% and 52.50% ($P > 0.05$). As can be seen from Table 5, in terms of the ratio of passive birds, the chickens with conventional lighting in the control group and the chickens with intermittent lighting in MBG group had the lowest mean values (22.50% and 23.75%, respectively, $P < 0.05$). In terms of the ratio of active animals, the mean values of the chickens in the control group and the intermittent lighting group were found to be higher than those of the other groups (37.50% and 32.50%, respectively, $P < 0.05$). This supports the view reported by Khaliq et al. (2018) and Hesham et al. (2018) that broilers reared under blue and green light are calmer. In addition, similar to the tonic immobility test results, it is thought that intermittent lighting causes fear and anxiety in animals, and the number of passive animals is low, and the number of active animals is high for the same reason in this experimental group. As can be seen in Table 6, there was no statistical difference between the groups in terms of the percentages of birds exhibiting avoidance and inspection behaviors (both $P > 0.05$). In addition, within the scope of the researcher's test behind the box, no fear behavior was observed in the animals in the experimental groups. These results show that this test is not very sensitive in measuring fear responses.

It is already known that green monochromatic lighting accelerates muscle growth and stimulates early growth (Halevy et al., 1998). In a study conducted by Soliman and Hassan (2019), it was claimed that the blue monochromatic lighting increased the secretion of metabolic hormones and significantly improved carcass weight and some performance traits compared to conventional white and red monochromatic lighting. Bayraktar and Altan (2005), who compared different light sources and blue and green LED lighting in broilers, reported that the carcass yield of chickens with blue and green LED lighting was higher than those of other groups. In a study by Mohamed et al. (2017), broiler chickens were treated with white, green, and blue monochromatic lighting. Researchers claimed that birds treated with white monochromatic lighting had higher average values (1400 g and 71.30%, respectively) in terms of both carcass weight and carcass yield. The results of this study, which are inconsistent with our study results and many other studies, are thought to be due to the animal material used. As can be seen from Table 7, the mean values of breast weight and back-neck weight of the broilers treated with green monochromatic lighting in the first ten days of the fattening period and then with blue monochromatic lighting were found to be higher than those of the other lighting groups ($P < 0.05$). Cao et al. (2008) who applied different monochromatic lighting programs in broilers, reported that the weights of carcass, breast, and thigh of broilers exposed to blue monochromatic lighting were higher than those of other groups. In addition, Ke et al. (2011) claimed that the carcass yield of broilers treated with blue monochromatic lighting was higher than those using green, white, and red monochromatic lighting. However, Liu et al. (2010) observed that birds reared under green monochromatic light had higher breast muscle weights than those of birds with blue, red, and white lighting.

Rozenboim et al. (2004a) and Classen et al. (2004) determined that green monochromatic lighting can increase the growth of young broilers more, while blue monochromatic lighting is more effective after the first period and warns the birds about growth. In this study, it was determined that broiler chickens treated with green monochromatic lighting for the first ten days and then blue monochromatic lighting had higher averages in terms of both growth performance and slaughter-carcass characteristics. When the findings of the tests performed to determine the fear state of the chickens were examined, it was determined that the worst results were in the intermittent lighting group (MBG), in which a blue and green light conversion was applied every five minutes. The second worst results were also found for broilers treated with green-blue combined monochromatic lighting (GB). As a result, it was determined that the application of green monochromatic lighting in the first ten days of the fattening period and blue monochromatic lighting in the following period positively affected growth and slaughter-carcass characteristics in line with the findings reported by Rozenboim et al. (2004a) and Classen et al. (2004). However, it was determined that broiler chickens reared under green-blue combined monochromatic lighting had high fear levels.

Declarations

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Conflict of Interest

The authors declare that they have no conflicts of interest.

Data availability

Not applicable

Code availability

Not applicable

Ethical statement

There is the decision of the Animal Experiments Local Ethics Committee of Akdeniz University, dated 18.10.2019 and numbered 128.

Author Contributions

All listed authors have made substantial contributions to the research design, or the acquisition, analysis, or interpretation of data, and drafting the manuscript or revising it critically. All authors have approved the submitted version.

References

1. Alkan, S., Narinç, D., Karslı, T., Karabağ, K. and Balcıoğlu, M.S., 2012. Effects of thermal manipulations during early and late embryogenesis on growth characteristics in Japanese quails (*Coturnix coturnix japonica*), Archiv für Geflügelkunde, 76, 184–190.
2. Barnett, J.L., Hemsworth, P.H. and Jones, R.B., 1993. Behavioural responses of commercially farmed laying hens to humans: evidence of stimulus generalization, Applied Animal Behaviour Science, 37, 139-146. https://doi.org/10.1016/0168-1591(93)90106-Y
3. Bayraktar, H. and Altan, A., 2005. Effects of light wavelength on broiler performance. Animal Production, 46, 22-32.

4. Campo, J.L. and Davila, S.G., 2002. Effect of photoperiod on heterophil to lymphocyte ratio and tonic immobility duration of chickens, Poultry science, 81, 1637-1639. https://doi.org/10.1093/ps/81.11.1637
5. Cao, J., Liu, W., Wang, Z., Xie, D., Jia, L. and Chen, Y., 2008. Green and blue monochromatic lights promote growth and development of broilers via stimulating testosterone secretion and myofiber growth, Journal of Applied Poultry Research, 17, 211-218. https://doi.org/10.3382/japr.2007-00043
6. Cao, J., Wang, Z., Dong, Y., Zhang, Z., Li, J., Li, F., and Chen, Y., 2012. Effect of combinations of monochromatic lights on growth and productive performance of broilers, Poultry Science, 91, 3013-3018. https://doi.org/10.3382/ps.2012-02413
7. Classen, HL., Annett, C.B., Schwean-Lardner, K.V., Gonda, R. and Derow, D., 2004. Effects of lighting programmes with twelve hours of darkness per day provided in one-, six- or twelve-hour intervals on the productivity and health of broiler chickens. British poultry science, 45, 31–32. https://doi.org/10.1080/00071660410001698137
8. Demuner, L.F., Suckeveris, D., Muñoz, J.A., Caetano, V.C., Lima, C.G.D., Faria, D.E.D. and Faria, D.E.D., 2017. Adjustment of growth models in broiler chickens. Pesquisa Agropecuária Brasileira, 52, 1241-1252. https://doi.org/10.1590/S0100-204X2017001200013
9. Fernandes, Q.C., Karthiayini, K., Ramnath, V., Kumar, R. and Radhika, G., 2018. Effect of exposure to monochromatic light on breast and thigh muscle fibre diameter of broiler chicken. The Pharma Innovation Journal ,7, 142–144.
10. Gongruttananun, N., and Guntapa, P., 2012. Effects of Red-Light Illumination on Productivity, Fertility, Hatchability and Energy Efficiency of Thai Indigenous Hens. Agriculture and Natural Resources, 46, 51-63.
11. Gross, W.B. and Siegel, P.B., 1982. Socialization as a factor in resistance to infection, feed efficiency, and response to antigen in chickens. American Journal of Veterinary Research, 43, 2010-2012.
12. Guevara, B.D.M., Pech, P.S., Zamora, B.R., Navarrete, S.L.F. and Magaña, S.H.F., 2015. Performance of broilers reared under monochromatic light emitting diode supplemental lighting. Brazilian Journal of Poultry Science, 17, 553-558. https://doi.org/10.1590/1516-635X1704553-558
13. Halevy, O., Biran, I. and Rozenboim, I., 1998. Various light source treatments affect body and skeletal muscle growth by affecting skeletal muscle satellite cell proliferation in broilers. Comparative Biochemistry and Physiology Part A: Molecular and Integrative Physiology, 120, 317-323. https://doi.org/10.1016/S1095-6433(98)10032-6
14. Hesham, M.H., El Shereen, A.H. and Enas, S.N., 2018. Impact of different light colors in behavior, welfare parameters and growth performance of Fayoumi broiler chickens' strain. Journal of the Hellenic Veterinary Medical Society, 69, 951-958. https://doi.org/10.12681/jhvms.18017
15. Huber-Eicher, B., Suter, A. and Spring-Stähli, P., 2013. Effects of colored light-emitting diode illumination on behavior and performance of laying hens. Poultry Science, 92, 869-873. https://doi.org/10.3382/ps.2012-02679

16. Jones, R.B., Duncan, IJH. and Hughes, BO., 1981. The assessment of fear in domestic hens exposed to a looming human stimulus. Behaviour Processes, 6, 121-133. https://doi.org/10.1016/0376-6357(81)90031-0
17. Jones, R.B., 1996. Fear and adaptability in poultry: insights, implications and imperatives. World's Poultry Science Journal, 52, 131-174. https://doi.org/10.1079/WPS19960013
18. Jones, R.B., 1987. Food neophobia and olfaction in domestic chicks. *Bird Behavior*, *7*, 78-81.
19. Jones, R.B., 1995. Ontogeny of response to humans in handled and non-handled female domestic chicks. Applied Animal Behaviour Science, 42, 261-269. https://doi.org/10.1016/0168-1591(94)00544-O
20. Jones, R.B., 1993. Reduction of the domestic chick's fear of human beings by regular handling and related treatments. Animal Behaviour, 46, 991-998. https://doi.org/10.1006/anbe.1993.1280
21. Karadavut, U., Taskin, A. and Genc, S., 2017. Comparison of growth curve models in Japanese quail raised in cages enriched with different colored lights. Revista Brasileira de Zootecnia, 46, 839-846. https://doi.org/10.1590/S1806-92902017001100002
22. Karakaya, M., Parlat, S.S., Yılmaz, M.T., Yıldırım, İ. and Özalp, B., 2009. Growth performance and quality properties of meat from broiler chickens reared under different monochromatic light sources. British poultry science, 50, 76-82. https://doi.org/10.1080/00071660802629571
23. Ke, Y.Y., Liu, W.J., Wang, Z.X. and Chen, Y.X., 2011. Effects of monochromatic light on quality properties and antioxidation of meat in broilers. Poultry Science, 90, 2632-2637. https://doi.org/10.3382/ps.2011-01523
24. Khaliq, T., Khan, A.A., Dar, P.A., Nazir, T., Afzal, I., Bilal, M. and Tarique, P., 2018. Behavioral study of broilers reared under different colours of light in the evening hours. Journal of Entomology and Zoology Studies, 6, 1624-1627.
25. Kram, Y.A., Mantey, S. and Corbo, J.C., 2010. Avian cone photoreceptors tile the retina as five independent, self-organizing mosaics. PloS One, 5, e8992. https://doi.org/10.1371/journal.pone.0008992.g001
26. Liu, W., Wang, Z. and Chen, Y., 2010. Effects of monochromatic light on developmental changes in satellite cell population of pectoral muscle in broilers during early posthatch period. The Anatomical Record: Advances in Integrative Anatomy and Evolutionary Biology, 293, 1315-1324. https://doi.org/10.1002/ar.21174
27. Marcato, S.M., Sakomura, N.K., Munari, D.P., Fernandes, J.B.K., Kawauchi, I.M. and Bonato, M.A., 2008. Growth and body nutrient deposition of two broiler commercial genetic lines. Brazilian Journal of Poultry Science, 10, 117-123.
28. Mohamed, R.A., Abou-Ismail, U.A. and Shukry, M., 2016. Effects of different monochromatic LED light colours on fear reactions and physiological responses in Mulard ducks. Animal Production Science, 57, 1128-1136. https://dx.doi.org/10.1071/AN15249
29. Mohamed, R.A., El-Kholya, S.Z., Shukry, M., El-Kassas, S. and El Saidy, N.R., 2017. Manipulation of Broiler Growth Performance, Physiological and Fear Responses Using Three Monochromatic LED

lights. Alexandria Journal for Veterinary Sciences, 53, 57–62. https://doi.org/10.5455/ajvs.263048

30. Narinç, D., Aksoy, T., Önenç, A. and ÇÜREK, D.İ., 2015. The influence of body weight on carcass and carcass part yields, and some meat quality traits in fast-and slow-growing broiler chickens. Kafkas Universitesi Veteriner Fakultesi Dergisi, 21, 527-534. https://doi.org/10.9775/kvfd.2014.12878
31. Narinç, D. and Genç, B.A., 2021. Genetic parameter estimates of fear, growth, and carcass characteristics in Japanese quail. Turkish Journal of Veterinary and Animal Sciences, 45, 272-280. https://doi.org/10.3906/vet-2007-43
32. Narinc, D., Karaman, E. and Aksoy, T., 2014. Effects of slaughter age and mass selection on slaughter and carcass characteristics in 2 lines of Japanese quail. Poultry Science, 93, 762-769. https://doi.org/10.3382/ps.2013-03506
33. Narinc, D., Narinç, N.Ö. and Aygün, A., 2017. Growth curve analyses in poultry science. World's Poultry Science Journal, 73, 395-408. https://doi.org/10.1017/S0043933916001082
34. Olanrewaju, H.A., Miller, W.W., Maslin, W.R., Collier, S.D., Purswell, J.L. and Branton, S.L., 2016. Effects of light sources and intensity on broilers grown to heavy weights Part 1: Growth performance, carcass characteristics, and welfare indices. Poultry science, 95, 727-735. https://doi.org/10.3382/ps/pev360
35. Olanrewaju, H.A., Thaxton, J.P., Dozier, W.A., Purswell, J., Roush, W.B. and Branton, S.L., 2006. A review of lighting programs for broiler production. International Journal of Poultry Science, 5, 301-308.
36. Prayitno, D.S., Phillips, C.J. and Omed, H., 1997. The effects of color of lighting on the behavior and production of meat chickens. Poultry Science, 76, 452-457. https://doi.org/10.1093/ps/76.3.452
37. Prescott, N.B., Wathes, C.M. and Jarvis, J.R., 2003. Light, vision and the welfare of poultry. Animal Welfare, 12, 269-288.
38. Rozenboim, I., Biran, I., Chaiseha, Y., Yahav, S., Rosenstrauch, A., Sklan, D. and Halevy, O., 2004. The effect of a green and blue monochromatic light combination on broiler growth and development. Poultry Science, 83, 842-845. https://doi.org/10.1093/ps/83.5.842
39. Rozenboim, I., Biran, I., Uni, Z., Robinzon, B. and Halevy, O., 1999. The effect of monochromatic light on broiler growth and development. Poultry Science, 78, 135-138. https://doi.org/10.1093/ps/78.1.135
40. Rozenboim, I., Huisinga, R., Halevy, O. and El Halawani, M.E., 2003. Effect of embryonic photostimulation on the post hatch growth of turkey poults. Poultry Science, 82, 1181-1187. https://doi.org/10.1093/ps/82.7.1181
41. Rozenboim, I., Piestun, Y., Mobarkey, N., Barak, M., Hoyzman, A. and Halevy, O., 2004. Monochromatic light stimuli during embryogenesis enhance embryo development and post hatch growth. Poultry Science, 83, 1413-1419. https://doi.org/10.1093/ps/83.8.1413
42. Sabuncuoğlu, K.M., Korkmaz, F., Gürcan, E.K., Narinç, D. and Şamlı, H.E., 2018. Effects of monochromatic light stimuli during embryogenesis on some performance traits, behavior, and fear responses in Japanese quails. Poultry Science, 97, 2385-2390. https://doi.org/10.3382/ps/pey105

43. Sen, S., Ingale, S.L., Kim, Y.W., Kim, J.S., Kim, K.H., Lohakare, J.D., Kim, H.S., Ryu, M.S., Kwon, I.K. and Chae, B.J., 2012. Effect of supplementation of Bacillus subtilis LS 1-2 to broiler diets on growth performance, nutrient retention, caecal microbiology and small intestinal morphology. Research in Veterinary Science, 93, 264-268. https://doi.org/10.1016/j.rvsc.2011.05.021
44. Solangi, A.H., Rind, M.I. and Solangi, A.A., 2004. Influence of lighting on production and agonistic behaviour of broiler. Journal of Animal and Veterinary Advances, 3, 285–288.
45. Soliman, E.S. and Hassan, R.A., 2019. Impact of lighting color and duration on productive performance and Newcastle disease vaccination efficiency in broiler chickens. Veterinary World, 12, 1052-1059. https://doi.org/10.14202/vetworld.2019.1052-1059
46. Sultana, S., Hassan, M.R., Choe, H.S. and Ryu, K.S., 2013. Impact of different monochromatic LED light colours and bird age on the behavioural output and fear response in ducks. Italian Journal of Animal Science, 12, 573-594. https://doi.org/10.4081/ijas.2013.e94
47. Sultana, S., Hassan, M.R., Choe, H.S. and Ryu, K.S., 2013. The effect of monochromatic and mixed LED light colour on the behaviour and fear responses of broiler chicken. Avian Biology Research, 6, 207-214. https://doi.org/10.3184/175815513X13739879772128
48. Topal, M. and Bölükbaşı, Ş.C., 2008. Comparison of nonlinear growth curve models in broiler chickens. Journal of Applied Animal Research, 34, 149-152. https://doi.org/10.1080/09712119.2008.9706960
49. Waiblinger, S., Boivin, X., Pedersen, V., Tosi, M.V., Janczak, A.M., Visser, E.K. and Jones, R.B., 2006. Assessing the human–animal relationship in farmed species: a critical review. Applied Animal Behaviour Science, 101, 185-242. https://doi.org/10.1016/j.applanim.2006.02.001
50. Xie, D., Wang, Z.X., Dong, Y.L., Cao, J., Wang, J.F., Chen, J.L. and Chen, Y.X., 2008. Effects of monochromatic light on immune response of broilers. Poultry Science, 87, 1535-1539. https://doi.org/10.3382/ps.2007-00317
51. Yang, Y., Pan, C., Zhong, R. and Pan, J., 2018. The quantitative models for broiler chicken response to monochromatic, combined, and mixed light-emitting diode light: a meta-analysis. Poultry Science, 97, 1980-1989. https://doi.org/10.3382/ps/pey065
52. Zhang, L., Zhang, H.J., Qiao, X., Yue, H.Y., Wu, S.G., Yao, J.H. and Qi, G.H., 2012. Effect of monochromatic light stimuli during embryogenesis on muscular growth, chemical composition, and meat quality of breast muscle in male broilers. Poultry Science, 91, 1026-1031. https://doi.org/10.3382/ps.2011-01899

Figures

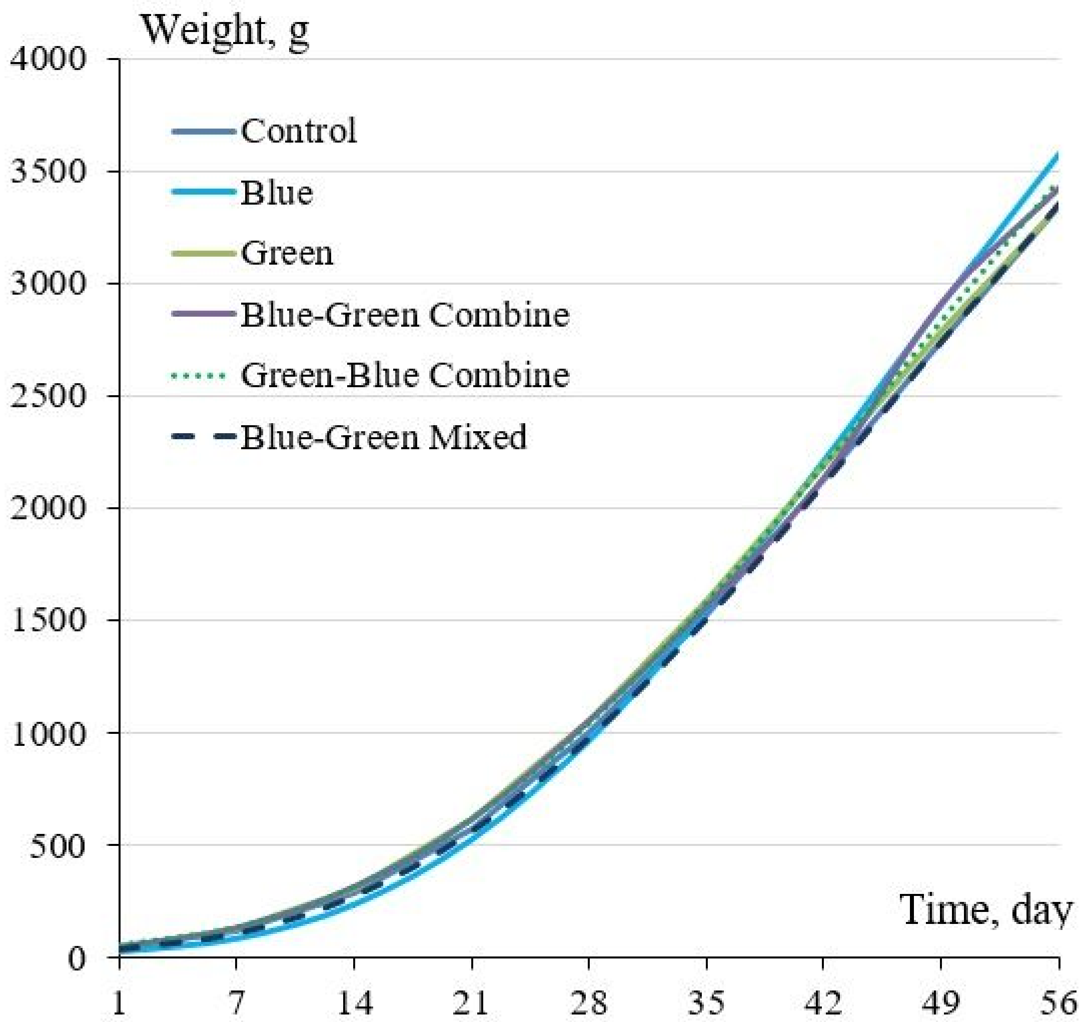

Figure 1

The Gompertz growth curves of broiler chickens by experimental groups