Animal Review
2023 Vol. 10, No. 1, pp. 1-11.
ISSN(e): 2409-6490
ISSN(p): 2412-3382
DOI: 10.18488/92.v10i1.3360

Impact of led lighting color on productive and behavioral characteristics of the broiler chickens

Albert R Reyad[1]
Gala Abou Khadiga[1]
Alaa E Elkomy[1,2+]
Ibraheim M Abaza[1]
Farid N K Soliman[3]

[1]*Faculty of Desert and Environmental Agriculture, Matrouh University, Matrouh, Egypt.*
[1]*Email: albertromil80@gmail.com*
[1]*Email: galal.aboukhadiga@mau.edu.eg*
[1]*Email: ibrahimabaza@mau.edu.eg*
[2]*Arid Lands Cultivation Research Institute, City of Scientific Research and Technology Application, Borg El-Arab, Egypt.*
[1,2]*Email: alaa_elkomy@yahoo.com*
[3]*Department of Animal and Poultry Production, Faculty of Agriculture, Alexandria University, Egypt.*
[3]*Email: nassif08@yahoo.com*


(+ Corresponding author)

Article History
Received: 6 February 2023
Revised: 12 April 2023
Accepted: 28 April 2023
Published: 9 May 2023

Keywords
Behavior
Broiler
LED
Light color.

ABSTRACT

The present study was conducted to investigate the effect of color (white and blue-green) of LED lighting on the productive, carcass and behavior traits of Cobb broiler chickens. Total of 200 one- day-old unsexed chicks were used, and divided into two pens/groups (100 birds of each with 25 birds of each replicate), at stocking density of 8.7 bird/ square meters. First pen used for LED white color and second pen for LED blue- green mix color light. The results showed that the birds exposed to blue-green light had significant higher (P≤0.01) BW, DBWG and FC values of the whole experimental period compared to those exposed to white color. However, the light color had no significant effect on FCR and MR measurements with average values 1.44 and 0.50%, respectively. The birds exposed to blue-green light had significant higher pre-slaughter live BW and carcass weights (P≤0.01) compared to those exposed to white color. The birds exposed to blue-green light had higher insignificant dressing percentage compared to those exposed to white color. The weekly behavior results showed highly significant differences (P≤0.01) among weeks for aggressiveness and immobility activities, while it being insignificant for pecking activity. The correlation value between immobility and five-week BW of birds reared under blue-green light was the only significant value (0.42) among all studied values. In conclusion, the results indicated that Cobb broilers were calmer under blue-green light compared to those reared under white light, which contributed in more better performance traits.

Contribution/Originality: Lighting plays an important role in the behavior and productivity of broiler chicks. LED bulbs are considered one of the modern lighting technologies, so this study was conducted to test the LED lighting lamps on the productivity of broiler chicks to improving productivity and saving the high cost of electrical energy when using ordinary lamps.

1. INTRODUCTION

The broiler production sector is characterized by a higher feed conversion rate comparison with other animals, where, each one kg of meat needs 2.0-2.5 kg feed, meanwhile, each one kg of red meat needs more than 7 Kg feed. Also, it has a higher economic return due to its short production cycle. The capital cycle of broiler production can be repeated seven times a year, and needs small area compared to other animals [1]. Moreover, the changing

patterns of human resource usage and food consumption have profoundly impacted the Earth's biosphere, broiler chickens are one such distinctive signs of this impact. However, broiler chickens now unable to survive without human intervention [2].

Breeders must adopt new technologies to meet this demand that will enable them to increase production at lower cost and with minimal stress on the environment. Most of these production techniques focus on enhancing traditional inputs such as water, air, nutrients and housing. Lighting and its characteristics need further clarification as a contributing factor to broiler productivity. Factors involved in light management for poultry include light source, intensity, duration, uniformity, and wavelength/color [3]. Artificial light in broiler production has a role in improving immunity [4, 5]. Increasing the immune response can reduce the risks of diseases and the costs of their treatment, which is reflected in higher levels of survival and lower production costs, which supports profitability [6]. By choosing the optimal light source and taking advantage of the unique spectral requirements of poultry, it is possible to maximize growth and efficiency, while, reducing stress and fostering ideal behavior [7].

Recently, light emitting diode (LED) lamps have been interesting in poultry production sector because of their more durable, and retain the light intensity for considerably longer periods [8], high energy efficiency [9], long operating life, availabile in different wavelengths, low electricity consumption, provides adequate illumination, which, led to low rearing cost [10].

the present study was designed to investigate the effect of color (white and blue-green) of LED lighting on the productive, carcass and behavior traits of Cobb broiler chickens.

2. MATERIAL AND METHODS

2.1. Experimental Design and Management

The present study was conducted at private farm in Marsa Matrouh city from 10 April to 14 May 2020. The aim of the study was to investigate the effect of color (white and blue-green) of LED lighting on the productive, carcass and behavior traits of Cobb broiler chickens.

Total of 200 one- day-old unsexed broiler chicks (Cobb strain) were purchased from Al-watania Poultry Company. The average weight of the chick at one- day-old was 42 ± 3.00 grams. The experiment was conducted using two open pens; each has 3.3 × 3.5 × 3.10 m for length, width and height, respectively. Each pen divided to four compartments (replicates), with repeated measures of 1.75X1.65 m. for length and width, respectively. The birds were divided into two groups (100 birds of each), then divided to 4 subgroups/replicates (25 birds of each), at stocking density of 8.7 bird/ square meters. A 70 cm high guard wire was used to separate the four replicates within each pen. Light emitting diode (LED) lamps (nine watts and 900 lumen) were installed in both pens. First pen used for LED white color (650nm) light and another pen for LED blue- green mix color light (430-565nm). Lamps were distributed as the distance between the lamps is twice the distance between the lamp and the wall, to ensure uniformity of illumination intensity. The lighting intensity was 25 lux, measured by lux meter each week. The lamps were cleaned from dust weekly for maintaining the intensity of light. The birds have the same managerial procedures in both pens throughout the experimental period (34 days of age).

2.2. Studied Traits

Live body weight (BW) and body weight gain (BWG) (as g) (for each bird) were recorded weekly per each treatment group. Feed consumption (FC) (as g) and feed conversion ratio (FCR) (as g feed intake /g body weight gain) were recorded for each replicate of each treatment.

Daily mortality of chicks (MR) was recorded and calculated as a percentage for both treatments for the whole experimental period. At the end of the experiment, five birds from each replicate of each treatment were randomly chosen, weighed individually and slaughtered with a sharp knife by cutting the jugular veins of the neck. Upon verification of complete bleeding, the feathers, viscera and other uneaten parts were removed and the carcass weight

of each bird measured. The dressing percentage expressed as carcass weight divided on live body weight was measured. Each carcass was cut into two parts (breast and thigh). The breast (half of the whole breast) and thigh (single thigh + drumstick) were weighed using a sensitive digital scale to the nearest 0.01 gram, and expressed as a relative to live body weight. Also, the gizzard, liver, heart and kidney were weighed, and expressed as a relative to live body weight.

2.3. Behavior Traits

Bird behavior was assessed on the basis of expression, where five birds were randomly selected from each replicate and painted black color on their backs weekly. The behavior of the birds was recorded using Samsung video camera with specifications:

- Sensor type: complementary metal-oxide semiconductor (CMOS).
- Video resolution: 1920×1080 pixels.
- Video FPS: 30 fps (frames per second).

The camera was placed at a height of 250cm to see the full pen. The registration of the behavior started on the fifth day. The behavior activities (immobility, aggressiveness and pecking) have been recorded as number/bird/hour for one hour each day between 10 pm to 11 pm.

Aggressiveness: Categorized as a bird attacking another bird, as well as pecking the feathers and bodies of other birds, and attempting to cause injuries [11, 12].

Immobility: Categorized as a bird that transited from a state of movement to a state of sitting and stability, meaning that the bird does not eat, drink or perform any action or activity, and that behavior reflects comfort [11, 13-15].

Pecking: Categorized as a bird that pecking litter, walls, and equipment, not other bird [16].

2.4. Statistical Analysis

In order to assess the effect of wavelengths of lighting on the performance of broiler chickens, data of all variables were subjected to analyses of variance (ANOVA) using the general linear models (GLM) procedure [17]. Significant differences among means were evaluated using Duncan multiple range test [18]. In addition, simple correlation (Pearson) values were estimated [17] between behavior and performance traits.

3. RESULT AND DISCUSSIONS

3.1. Performance Traits

At the end of the experimental period, the results of Table 1 showed significant effect between studied light treatments on five-week body weight (BW), daily body weight gain (DBWG), and feed consumption (FC) values, while it being in significant on feed conversion ratio (FCR) and mortality rate (MR) values.

Table 1. Mean and standard error (μ±SE) of performance traits of cobb broiler strain exposed to different LDL colors during fattening period.

Age (Week)	Treatments		Overall mean	*P*-value
	White light	Blue-green light		
5-wk BW	44.51 ±2177.20^{b}	46.24 ±2317.97^{a}	32.60± 2247.58	0.03**
0-5wk DBWG	5.47± 61.01^{b}	1.32 ±65.03^{a}	0.93 ±63.02	0.03**
0-5wk FC	3068.27^{b} ± 3.28	3115.17^{a} ± 3.57	3091.72 ± 3.23	0.00**
0-5wk FCR	1.48 ± 0.03	1.40 ± 0.03	1.44 ± 0.02	0.11^{NS}
0-5wk MR	0.60 ± 0.24	0.40 ± 0.24	0.50 ± 0.17	0.37^{NS}

Note: NS: Non significant, **: P<0.01, Mean values with different superscripts within a row differ significantly.

The birds exposed to blue-green light had significant higher BW, DBWG and FC values of the whole experimental period at (2317.97, 65.03 and 3115.17g, respectively) compared to those exposed to white color

(2177.20, 61.01, 3068.27g, respectively). However, the overall mean of FCR and MR values for both treatments were 1.44 and 0.50%, respectively.

The findings of BW and DBWG are in agreement with the results of Mosa, et al. [19]; Senaratna, et al. [20] and Balabel, et al. [21] who found that blue – green light among other light colors showed to be enhancer for growth BW in their studies with Ross 308, Cobb and Cobb broiler chickens, respectively. Moreover, broilers chickens reared under blue and green monochromatic light experienced increased BW compared to broilers exposed to white or red light [22-25]. Moreover, Nelson, et al. [26] found that Ross 708 broilers reared under white LED supplemented with blue/green light had higher overall day 45 live body weight than birds reared under only white LED light.

In contrast, the red light showed to has higher preference and improved BWG compared to green, blue and white color lights [27]. However, other studies have reported no effect of light wavelength on BW and BWG [28, 29].

To better understand the increased growth of broilers reared under green light, Liu, et al. [30] found that satellite cell mitotic activity increased under green light compared to blue and red light. However, both blue and green lights had improved as insulin-like growth factor levels compared to red light. In respect of blue lighting, Asih, et al. [31] illustrated that it makes the broiler chicken quieter and have less activity after meal so the excess energy can be converted into feeding, hence enhance the growth rate.

The present FC and FCR results are in consistent with several studies indicate that light wavelength seems to stimulate broiler growth without significant effects on total FCR [15, 28, 29, 32, 33]. In addition, Mohamed, et al. [25] showed that Avian 48 broiler chicks reread under green and blue lights has significant higher FC and lower FCR at 40 days of age compared to those reread under white color light. Also, Balabel, et al. [21] found that the total FC were significantly lower in blue and/or G-BL groups compared to white and green color groups (4676, 4590g, 4830 and 4795g, respectively), with significant decreasing effect also on FCR values (1.82, 1.75, 2.38, 1.98, respectively).

Melatonin hormone synthesized by the pineal gland, retina and gastrointestinal tract, whose main function is to determine the periodicity of FC, as well as to induce behaviors associated with the night- day cycle [34]. In addition, Asih, et al. [31] showed that broilers treated with the blue lighting for 24-hour or for 12-hour have significant longer feeding duration, lower feeding frequency, and lower FCR when compared to those of chickens with control lighting.

The MR results of the present study confirms the previous finding of Rozenboim, et al. [35]; Cao, et al. [32] and Ke, et al. [33] who reported that blue light seems to stimulate broiler growth at the end of the production cycle without significant effects on mortality rate. Kasem [36] found that broiler Cobb chicks reared under mixed green-blue and blue light has the lower mortality rate compared to white light group.

Table 2. Mean and standard error (μ±SE) of carcass traits of Cobb broiler strain exposed to different LDL colors during fattening period.

Age	Treatments		Overall mean	*P*-value
	White light	Blue-green light		
Body weight	77.75 ±2388.00^{b}	54.87 ±2624.25^{a}	50.63±2506.13	0.02**
Carcass weight	60.47 ±1814.25^{b}	41.05 ±2014.75^{a}	39.48±1914.50	0.01**
Dressing (%)	0.61±75.35	0.0.50±76.00	0.39±76.40	0.27^{NS}
Breast (%)	30.36 ± 0.60	30.26 ± 0.41	30.31 ± 0.36	0.79 ^{NS}
Thigh (%)	19.21 ± 0.21	19.75 ± 0.39	19.48 ± 0.28	0.34 ^{NS}
Liver (%)	2.55 ± 0.15	2.21 ± 0.08	2.38 ± 0.09	0.05*
Gizzard (%)	1.86 ± 0.06	1.72 ± 0.05	1.79 ± 0.04	0.07 ^{NS}
Heart (%)	0.48 ± 0.02	0.46 ± 0.02	0.47 ± 0.01	0.51 ^{NS}
Kidney (%)	0.53^{a} ± 0.01	0.50^{b} ± 0.01	0.52 ± 0.01	0.02**

Note: NS: Non significant, *: P<0.05, **: P<0.01, a.b,c Mean values with different superscripts within a row differ significantly.

However, Balabel, et al. [21] found that mortality rate of Cobb broiler chicks has significant influence among light color treatments (5.00, 3.33, 3.33 and 1.67% for white, green, blue and blue-green lighting, respectively). Abdel-Azeem and Borham [37] revealed that Ross- 308 broiler chickens exposed to LED-blue light or LED-green light during 7 to 35 days of age showed significant higher livability percentages than those exposed to other light colors (incandescent light, red, white and mixed LED lights) groups (95.12, 94.43, 86.59, 92.51, 88.50 and 89.20%, respectively).

The findings of carcass weight and dressing percentages of Cobb broiler chickens (Table 2) showed significant differences between studied light treatments for pre-slaughter live BW and carcass weight values, however it being insignificant for dressing percentage values. The birds exposed to blue-green light had significant higher live BW and carcass weights (2624.25 and 2388.00g, respectively) compared to those exposed to white color (2014.75 and 1814.25g, respectively). Regardless the insignificant differences for dressing percentages values, the birds exposed to blue-green light had higher dressing percentage compared to those exposed to white color (76.00 and 75.35%, respectively). The relative breast and thigh + drumstick weights of the Cobb broiler (Table 2) showed insignificant differences between studied light treatments for relative breast and thigh + drumstick weights values, with overall mean were 30.31 and 19.48%, respectively. The relative weights of liver, gizzard and heart weight of Cobb broiler chickens were insignificant between both studied lights, with overall mean were 2.38, 1.79 and 0.47%, respectively. However, the Cobb broiler chickens reared under white light has significant higher relative kidney weight compared to those reared under blue-green light (0.53 and 0.50%, respectively).

The present results of dressing percentage values are consistent with the findings of Santana, et al. [28] and Olanrewaju, et al. [29] who reported no effect of light color on carcass yield at different slaughter ages. Moreover, Nelson, et al. [26] showed that straight run Ross 708 broilers reared under white LED supplemented with blue/green light had higher carcass yield more than birds reared under only white LED light. In addition, Sayin, et al. [38] explained that the broiler chicks raised under mixed blue and green lighting recorded a higher body weight than birds raised under monochromatic light (white, blue, green) at the age of 42 and 56 days. However, Cao, et al. [32] found a greater carcass yield for broiler chickens subjected to blue LED lighting.

In contrast, Mosa, et al. [19] showed, regardless stocking density, that the carcass weight (1406.44g) and dressing percentage (74.16%) were significantly higher at 35th day in Ross 308 broilers exposed to Blue – Green mix light compared to other color treatments (white, red, blue and green lights).

Mohamed, et al. [25] showed that Avian 48 broiler chicks reread under green and blue lights has significant higher dressing percentage at 40 days of age compared to those reread under white color light (75.10, 75.90 and 71.30%, respectively).

Divergence among our results to the literature findings could be related to genetic strain, age, management and environmental conditions.

Similar to the present breast and thigh + drumstick weights results, Santana, et al. [28] found insignificant differences for cuts percentage (breast and thigh + drumstick) among light treatments (red-LED, blue-LED and fluorescent bulb) light. Also, the present results indicating that breast have highest portion among cuts up of broiler carcass, which are in line with all studies in that field. However, Cao, et al. [32] found a greater breast, and thigh yield for broiler chickens subjected to blue LED lighting. Liu, et al. [30] found that birds reared under green light had higher breast muscle weight than those reared under blue, red, and white light.

The present organ results are in agreement with the findings of Mosa, et al. [19] who studied different light colors (red, blue, green and blue-green lights) and observed insignificant differences effect on relative liver and gizzard weights of Ross 308 broiler chicks at 35 days of age, while positive effect of heart percentage was recorded in broilers reared under green light (0.64%), with no effect for stocking density in that respect. However, Mohamed, et al. [25] showed that Avian 48 broiler chicks reread under green and blue lights has significant lower relative

liver weight at 40 days of age compared to those reread under white color light (0.960, 0.958and 1.24 %, respectively).

The results of behavior activities of Cobb broiler strain (Table 3) showed highly significant differences for all studied behavior traits. The results observed significant lower aggressiveness and pecking activities, while significant higher immobility activity for chicks reared under mixed green – blue light color (12.64, 103.86 and 170.07 number/bird/hour, respectively) compared to the corresponding values recoded for those reared under white light color (38.43, 464.29 and 113.79 number/bird/hour, respectively).

Table 3. Mean and standard Error of some behavior activities (number/bird/hour) of Cobb broiler strain exposed to different LDL colors during fattening period.

Activities	Aggressiveness	Immobility	Pecking
Treatments			
White	$38.43^{a} \pm 5.81$	$113.79^{b} \pm 7.34$	$464.29^{a} \pm 56.21$
Green- blue	$12.64^{b} \pm 3.48$	$170.07^{a} \pm 6.31$	$103.86^{b} \pm 34.21$
P-value	0.00	0.00	0.00
Overall average	25.54 ± 3.78	141.93 ± 6.12	284.07 ± 40.66
Week intervals			
1st	$64.00^{a} \pm 12.54$	$89.00^{b} \pm 14.53$	329.00 ± 133.06
2nd	$45.57^{b} \pm 8.87$	$134.71^{a} \pm 12.49$	361.86 ± 89.18
3rd	$22.57^{c} \pm 6.36$	$157.07^{a} \pm 14.87$	379.57 ± 98.88
4th	$10.43^{c} \pm 3.16$	$135.57^{a} \pm 10.21$	173.57 ± 54.41
5th	$7.40^{c} \pm 2.25$	$160.90^{a} \pm 7.99$	178.20 ± 82.35
P-value	0.00	0.00	0.76
Overall average	25.54 ± 3.78	141.93 ± 6.12	284.07 ± 40.66

Note: Means in the same column having different superscripts in certain effect are significantly different ($P \leq 0.05$).
Aggressiveness: Categorized as a bird attacking another bird, as well as pecking the feathers and bodies of other birds, and attempting to cause injuries.
Immobility: Categorized as a bird that transited from a state of movement to a state of sitting and stability.
Pecking: Categorized as a bird that pecking litter, walls, and equipment, not other bird.

The Cobb broiler chickens in the present study are significantly less active under mixed blue - green light compared to white light. These results are consistent with the findings of Cao, et al. [32]; Cao, et al. [22]; Liu, et al. [30]; Mendes, et al. [39]; Xie, et al. [40]; Senaratna, et al. [27]; Abu Tabeekh and Shawkat [11]; Hesham, et al. [15] and Mohamed, et al. [41] in their comparative studies of different light colors, who found that blue and/or green lights helped to regulate aggressiveness and other related behaviors, inducing calm broiler chickens, thereby providing optimum performance. Sultana, et al. [13] pointed out that the red and red-yellow light activates movements and fear response in broiler chicken, while blue and green/blue keep broilers calmer. Kasem [36] showed that the rest and sleep time of Cobb chicks increase under mixed green blue and blue light color groups compared to white light group. Khaliq, et al. [42] revealed that birds reared under blue and green light were calmer and more relaxed while as those reared under red or yellow light exhibited aggressiveness. Abdel-Azeem and Borham [37] showed that Ross-308 broiler chickens were calmer under LED-blue light with 10 birds /m2 in broiler house which is preferable to other colors (red, green and white) and densities. Franco, et al. [43] also showed that broiler chickens at the age of 33 to 34 days spent more time resting under blue light.

The results of weekly behavior activities (Table 3) showed highly significant differences among weeks for aggressiveness and immobility activities, while it being insignificant for pecking activity. Regardless the color of light, the current results showed that aggressive activity has descending manner with age (64.00, 45.57, 22.57, 10.43 and 7.44 number/bird/hour for 1st, 2nd, 3th, 4th and 5th week, respectively). However, there is a swinging trend in immobility values with age activity, but in general it increases significantly, since the 1st week showed significant lesser ones. Regard to the pecking activity, although there are no significant differences among weeks, the fourth and fifth weeks are the least effective for this activity.

Current behavioral results have found that Cobb broiler chickens become calm with the advance of age; these findings are in line, as has been shown in numerous previous studies [e.g., [44-48]] they reported that the broilers

have been found to become increasingly inactive with age. Sultana, et al. [13] showed that age affected most behavioural patterns. The Ross×Ross 308 broiler chicks, regardless the color of lighting, recorded 31.07, 31.99, 34.62, 38.75 and 40.56 minute/hour during for sitting and 28.94, 23.33, 26.99, 16.89and 11.89 n/bird/h for ground pecking during 1st, 2nd, 3th, 4th and 5th weeks of age, respectively.

The rapid growth of broilers' breast muscles moves the center of body gravity forward and the legs outward, that produce a gait pattern is probably inefficient and tiring [49]. In addition, broilers may find walking painful [50] because they are increasingly prone to leg disorders [51].

Differences among studies in this area have been reported to differences in breed, age, diet, feeding methods, litter, social rank, light (quality, intensity, photoperiod, and color), record method of observations, duration of exposure to light, flock size/stocking density, experiment procedures and so on. Also, morphological factors such as comb type, plumage pattern and color. Thus, the behavior of chickens is a function of interaction among genes, phenotypes, and the environment.

Table 4. Phenotype correlation (Pearson) values between behavior traits and some performance traits of Cobb broiler strain reared under white and blue-green light.

Treatments	Behaviour activities	Carcass weight	Dressing percentage	BW 5wk	DBWG 0-5wk	FC 0-5wk	FCR 0-5wk
White light	Aggressiveness	-0.288	-0.243	-0.024	-0.147	-0.280	0.116
	Immobility	-0.201	0.085	0.350	0.101	0.079	-0.162
	Pecking	-0.242	0.308	0.181	0.161	-0.144	-0.210
Blue-green light	Aggressiveness	-0.077	-0.163	-0.214	-0.082	-0.190	0.039
	Immobility	-0.032	-0.012	0.419*	0.159	0.008	-0.187
	Pecking	-0.156	0.088	0.060	-0.011	-0.216	-0.054

Note: *significant at ($P \leq 0.05$).
Aggressiveness: Categorized as a bird attacking another bird, as well as pecking the feathers and bodies of other birds, and attempting to cause injuries.
Immobility: Categorized as a bird that transited from a state of movement to a state of sitting and stability.
Pecking: Categorized as a bird that pecking litter, walls, and equipment, not other bird.

The results of phenotype correlation values (Table 4) between studied behavior traits and some performance traits of Cobb broiler strain reared under white and blue-green light, showed that all the correlation values of birds reared under white light has insignificant negative and positive values. The values of aggressiveness with all studied performance traits were negative, except with zero-five-week FCR it being positive. This result indicated that the increase of aggressiveness activity has insignificant reduction effect on all studied performance traits, whereas it increased zero-five-week FCR (positive value, 0.12). In addition, the increase of immobility and pecking activities decreased zero-five-week FCR (negative values, -0.16 and -0.21, respectively). Also, both later activities have positive correlation values with five-week BW and zero-five-week DBWG traits. This result indicated that the increase of immobility and pecking activities increase these traits.

On the other hand, the phenotype correlations of behavior traits and performance traits of birds reared under blue-green light has insignificant negative and positive values, except the correlation value between immobility activity and five-week BW trait it being significant (0.42). This result indicated that the increase of immobility activity increases significantly the five-week BW of the birds reared under blue-green light. Also, the behavior traits have the same trend of correlation values with zero-five-week FCR traits, which revealed that the increase of aggressiveness activity increase zero-five-week FCR (0.04), whereas the increase of immobility and pecking activity decrease zero-five-week FCR (-0.19 and -0.05, respectively).

Most studies in literature were focused on feeding behavior traits and their relationship with live performance traits in broilers [e.g., [52-54]] and duck [55]. However, the results of phenotypic correlations in the present study support the previous finding of Hakan and Ali [56] who showed that shorter wavelength had positive effect on broiler performance compared to higher wavelength. Also, Tickle, et al. [57] found that locomotion is relatively energetically expensive in Cobb500 broilers.

4. CONCLUSION

The present results indicated that Cobb broilers were calmer under blue-green light compared to those reared under white light, which contributed in better performance traits. This result encourages the use of mixed blue-green lighting to raise broiler chicks in an appropriate environment and supports the welfare of birds.

Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study.

REFERENCES

[1] N. D. Wahyono and M. M. D. Utami, "A review of the poultry meat production industry for food safety in Indonesia," presented at the IOP Conference Series: Journal of Physics: Conference Series No. 953, 2018.

[2] C. E. Bennett *et al.*, "The broiler chicken as a signal of a human reconfigured biosphere," *Royal Society Open Science*, vol. 5, no. 12, p. 180325, 2018. https://doi.org/10.1098/rsos.180325

[3] H. Ç. Akyüz and E. Onbaşilar, "Light wavelength on different poultry species," *World's Poultry Science Journal*, vol. 74, no. 1, pp. 79-88, 2018. https://doi.org/10.1017/s0043933917001076

[4] H. Bayraktar, A. Altan, and C. Seremet, "The effects of spot lighting on broiler performance and welfare," *Journal of Animal and Veterinary Advances*, vol. 11, no. 8, pp. 1139-1144, 2012. https://doi.org/10.3923/javaa.2012.1139.1144

[5] R. Blatchford, G. Archer, and J. Mench, "Contrast in light intensity, rather than day length, influences the behavior and health of broiler chickens," *Poultry Science*, vol. 91, no. 8, pp. 1768-1774, 2012. https://doi.org/10.3382/ps.2011-02051

[6] H.-S. Seo *et al.*, "Effects of various LED light colors on growth and immune response in broilers," *The Journal of Poultry Science*, vol. 53, no. 1, pp. 76-81, 2015. https://doi.org/10.2141/jpsa.0150046

[7] G. S. Archer, "Comparison of incandescent, CFL, LED and bird level LED lighting: Growth, fear and stress," *International Journal of Poultry Science*, vol. 14, no. 8, pp. 449-455, 2015. https://doi.org/10.3923/ijps.2015.449.455

[8] N. Khan and N. Abas, "Comparative study of energy saving light sources," *Renewable and Sustainable Energy Reviews*, vol. 15, no. 1, pp. 296-309, 2011. https://doi.org/10.1016/j.rser.2010.07.072

[9] B. Huber-Eicher, A. Suter, and P. Spring-Stähli, "Effects of colored light-emitting diode illumination on behavior and performance of laying hens," *Poultry Science*, vol. 92, no. 4, pp. 869-873, 2013. https://doi.org/10.3382/ps.2012-02679

[10] A. G. Rogers, E. M. Pritchett, R. L. Alphin, E. M. Brannick, and E. R. Benson, "I. Evaluation of the impact of alternative light technology on male broiler chicken growth, feed conversion, and allometric characteristics," *Poultry Science*, vol. 94, no. 3, pp. 408-414, 2015. https://doi.org/10.3382/ps/peu045

[11] M. A. S. Abu Tabeekh and T. F. Shawkat, "Effect of light color and stocking density on some behavioral traits of broilers and layers," *Journal of Agricultural Science and Soil Science*, vol. 3, no. 9, pp. 122-130, 2015.

[12] C. Nie, L. Ban, Z. Ning, and L. Qu, "Feather colour affects the aggressive behaviour of chickens with the same genotype on the dominant white (I) locus," *Plos One*, vol. 14, no. 5, p. e0215921, 2019. https://doi.org/10.1371/journal.pone.0215921

[13] S. Sultana, M. R. Hassan, H. S. Choe, and K. S. Ryu, "The effect of monochromatic and mixed LED light colour on the behaviour and fear responses of broiler chicken," *Avian Biology Research*, vol. 6, no. 3, pp. 207-214, 2013. https://doi.org/10.3184/175815513x13739879772128

[14] N. Kim, S.-R. Lee, and S.-J. Lee, "Effects of light color on energy expenditure and behavior in broiler chickens," *Asian-Australasian Journal of Animal Sciences*, vol. 27, no. 7, pp. 1044-1049, 2014. https://doi.org/10.5713/ajas.2012.12425

[15] M. Hesham, A. El Shereen, and S. Enas, "Impact of different light colors in behavior, welfare parameters and growth performance of Fayoumi broiler chickens strain," *Journal of the Hellenic Veterinary Medical Society*, vol. 69, no. 2, pp. 951-958, 2018. https://doi.org/10.12681/jhvms.18017

[16] A. C. Lucena, H. Pandorfi, G. L. Almeida, C. Guiselini, J. E. Araújo, and T. P. D. S. Rodrigues, "Behavior of broilers subjected to different light spectra and illuminances," *Brazilian Journal of Agricultural and Environmental Engineering*, vol. 24, no. 6, pp. 415-421, 2020. https://doi.org/10.1590/1807-1929/agriambi.v24n6p415-421

[17] SPSS, *IBM corp. Released 2016. IBM SPSS statistics for windows, version 20.0.* Armonk, NY: IBM Corp, 2016.

[18] D. B. Duncan, "Multiple range and multiple F-test," *Biometrics*, vol. 11, pp. 1-5, 1955. http://dx.doi.org/10.2307/3001478

[19] R. Mosa, R. Abbas, and M. Tabeekh, "An investigation on light color and stocking density on some productive performance of broilers," *Basrah Journal of Veterinary Research*, vol. 14, no. 1, pp. 176-186, 2015. https://doi.org/10.33762/bvetr.2015.100463

[20] D. Senaratna, T. Samarakone, and W. Gunawardena, "Red color light at different intensities affects the performance, behavioral activities and welfare of broilers," *Asian-Australasian Journal of Animal Sciences*, vol. 29, no. 7, pp. 1052-1059, 2016. https://doi.org/10.5713/ajas.15.0757

[21] T. Balabel, R. Mohamed, and M. Saleh, "Using different light colors as a stress factor on broiler performance in Egypt," *Australian Journal of Basic and Applied Sciences*, vol. 11, no. 9, pp. 165-170, 2017.

[22] J. Cao *et al.*, "Effect of combinations of monochromatic lights on growth and productive performance of broilers," *Poultry Science*, vol. 91, no. 12, pp. 3013-3018, 2012. https://doi.org/10.3382/ps.2012-02413

[23] M. Kim *et al.*, "Growth performance and hematological traits of broiler chickens reared under assorted monochromatic light sources," *Poultry Science*, vol. 92, no. 6, pp. 1461-1466, 2013. https://doi.org/10.3382/ps.2012-02945

[24] M. R. Hassan, S. Sultana, H. S. Choe, and K. S. Ryu, "Effect of combinations of monochromatic LED light color on the performance and behavior of laying hens," *The Journal of Poultry Science*, vol. 51, no. 3, pp. 321-326, 2014. https://doi.org/10.2141/jpsa.0130105

[25] R. Mohamed, S. El-Kholya, M. Shukry, S. El-Kassas, and N. El-Saidy, "Manipulation of broiler growth performance, physiological and fear responses using three monochromatic LED lights," *Alexandria Journal of Veterinary Sciences*, vol. 53, no. 1, pp. 57-62, 2017. https://doi.org/10.5455/ajvs.263048

[26] J. R. Nelson, J. L. Bray, J. Delabbio, and G. S. Archer, "Light emitting diode (LED) color and broiler growth: Effect of supplementing blue/green LED to white LED light on broiler growth, stress, and welfare," *Poultry Science*, vol. 99, no. 7, pp. 3519-3524, 2020. https://doi.org/10.1016/j.psj.2020.04.020

[27] D. Senaratna, T. Samarakone, A. Madusanka, and W. Gunawardane, "Performance, behaviour and welfare aspects of broilers as affected by different colours of artificial light," *Tropical Agricultural Research and Extension*, vol. 14, no. 2, pp. 38-44, 2012. https://doi.org/10.4038/tare.v14i2.4840

[28] M. R. D. Santana, R. G. Garcia, I. D. A. Naas, I. C. Paz, F. R. Caldara, and B. Barreto, "Light emitting diode (LED) use in artificial lighting for broiler chicken production," *Agricultural Engineering*, vol. 34, no. 3, pp. 422-427, 2014. https://doi.org/10.1590/s0100-69162014000300005

[29] H. Olanrewaju, J. Purswell, S. Collier, and S. Branton, "Effects of color temperatures (Kelvin) of LED bulbs on blood physiological variables of broilers grown to heavy weights," *Poultry Science*, vol. 94, no. 8, pp. 1721-1728, 2015. https://doi.org/10.3382/ps/pev139

[30] W. Liu, Z. Wang, and Y. Chen, "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*, vol. 293, no. 8, pp. 1315-1324, 2010. https://doi.org/10.1002/ar.21174

[31] D. R. Asih, S. Harimurti, and W. Wihandoyo, "The effect of 12 and 24-hour blue lighting on performance and feeding behavior of broiler chickens," *Livestock Newsletter*, vol. 42, no. 1, pp. 15-19, 2018. https://doi.org/10.21059/buletinpeternak.v42i1.25696

[32] J. Cao, W. Liu, Z. Wang, D. Xie, L. Jia, and Y. Chen, "Green and blue monochromatic lights promote growth and development of broilers via stimulating testosterone secretion and myofiber growth," *Journal of Applied Poultry Research*, vol. 17, no. 2, pp. 211-218, 2008. https://doi.org/10.3382/japr.2007-00043

[33] Y. Ke, W. Liu, Z. Wang, and Y. Chen, "Effects of monochromatic light on quality properties and antioxidation of meat in broilers," *Poultry Science*, vol. 90, no. 11, pp. 2632-2637, 2011. https://doi.org/10.3382/ps.2011-01523

[34] H. Huang, Z. Wang, S.-J. Weng, X.-H. Sun, and X.-L. Yang, "Neuromodulatory role of melatonin in retinal information processing," *Progress in Retinal and Eye Research*, vol. 32, pp. 64-87, 2013. https://doi.org/10.1016/j.preteyeres.2012.07.003

[35] I. Rozenboim *et al.*, "The effect of a green and blue monochromatic light combination on broiler growth and development," *Poultry Science*, vol. 83, no. 5, pp. 842-845, 2004. https://doi.org/10.1093/ps/83.5.842

[36] M. M. S. Kasem, "Impact of light management on broilers behavior and performance," MSc. Thesis, Faculty of Veterinary Medicine, Kfr El-Sheikh University Egypt, 2017.

[37] A. Abdel-Azeem and B. Borham, "Productive and physiological response of broiler chickens exposed to different colored light-emitting diode and reared under different stocking densities," *Egyptian Poultry Science Journal*, vol. 38, no. 4, pp. 1243-1264, 2018. https://doi.org/10.21608/epsj.2019.23694

[38] Y. Sayin, O. Kaplan, E. Karaduman, D. Haqyar, and D. Narinç, "The effect of monochromatic, combined, and mixed light-emitting diode light regimes on growth traits, fear responses, and slaughter-carcass characteristics in broiler chickens," *Tropical Animal Health and Production*, vol. 54, no. 5, pp. 277-277, 2022. https://doi.org/10.21203/rs.3.rs-1448612/v1

[39] A. S. Mendes, R. Reffat, R. Restelatto, and S. J. Paixão, "Vision and lighting in modern poultry," *Brazilian Journal of Agroscience*, vol. 16, no. 1, pp. 5-13, 2010.

[40] D. Xie *et al.*, "Effects of monochromatic light on mucosal mechanical and immunological barriers in the small intestine of broilers," *Poultry Science*, vol. 90, no. 12, pp. 2697-2704, 2011. https://doi.org/10.3382/ps.2011-01416

[41] R. Mohamed *et al.*, "Effect of different monochromatic LED light colour and intensity on growth performance, physiological response and fear reactions in broiler chicken," *Italian Journal of Animal Science*, vol. 19, no. 1, pp. 1099-1107, 2020. https://doi.org/10.1080/1828051x.2020.1821802

[42] T. Khaliq *et al.*, "Behavioral study of broilers reared under different colours of light in the evening hours," *Journal of Entomology and Zoology Studies*, vol. 6, no. 4, pp. 1624-1627, 2018.

[43] B. R. Franco *et al.*, "Light color and the commercial broiler: Effect on behavior, fear, and stress," *Poultry Science*, vol. 101, no. 11, p. 102052, 2022.

[44] D. Bizeray, C. Leterrier, P. Constantin, M. Picard, and J. Faure, "Sequential feeding can increase activity and improve gait score in meat-type chickens," *Poultry Science*, vol. 81, no. 12, pp. 1798-1806, 2002. https://doi.org/10.1093/ps/81.12.1798

[45] D. Bizeray, C. Leterrier, P. Constantin, M. Picard, and J. Faure, "Early locomotor behaviour in genetic stocks of chickens with different growth rates," *Applied Animal Behaviour Science*, vol. 68, no. 3, pp. 231-242, 2000. https://doi.org/10.1016/s0168-1591(00)00105-2

[46] T. Cornetto and I. Estevez, "Behavior of the domestic fowl in the presence of vertical panels," *Poultry Science*, vol. 80, no. 10, pp. 1455-1462, 2001. https://doi.org/10.1093/ps/80.10.1455

[47] S. Shields, J. Garner, and J. Mench, "Effect of sand and wood-shavings bedding on the behavior of broiler chickens," *Poultry Science*, vol. 84, no. 12, pp. 1816-1824, 2005. https://doi.org/10.1093/ps/84.12.1816

[48] H. H. Kristensen *et al.*, "The behaviour of broiler chickens in different light sources and illuminances," *Applied Animal Behaviour Science*, vol. 103, no. 1-2, pp. 75-89, 2007. https://doi.org/10.1016/j.applanim.2006.04.017

[49] S. Corr, M. Gentle, C. McCorquodale, and D. Bennett, "The effect of morphology on walking ability in the modern broiler: A gait analysis study," *Animal Welfare*, vol. 12, no. 2, pp. 159-171, 2003. https://doi.org/10.1017/s0962728600025616

[50] T. Danbury, C. Weeks, A. Waterman-Pearson, S. Kestin, and J. Chambers, "Self-selection of the analgesic drug carprofen by lame broiler chickens," *Veterinary Record*, vol. 146, no. 11, pp. 307-311, 2000.

[51] J. A. Mench, "Leg problems. In measuring and auditing broiler welfare. C.A. Weeks and A. Butterworth ed." Wallingford, UK: CAB, 2004, pp. 3–17.

[52] J. Howie, S. Avendano, B. Tolkamp, and I. Kyriazakis, "Genetic parameters of feeding behavior traits and their relationship with live performance traits in modern broiler lines," *Poultry Science*, vol. 90, no. 6, pp. 1197-1205, 2011. https://doi.org/10.3382/ps.2010-01313

[53] J. Teng *et al.*, "Relationship between feeding behavior and production performance of broiler chickens based on automatic feeding system," *Journal of South China Agricultural University*, vol. 39, no. 4, pp. 7-12, 2018.

[54] W. Yan, C. Sun, C. Wen, C. Ji, D. Zhang, and N. Yang, "Relationships between feeding behaviors and performance traits in slow-growing yellow broilers," *Poultry Science*, vol. 98, no. 2, pp. 548-555, 2019.

[55] T. Bley and W. Bessei, "Recording of individual feed intake and feeding behavior of Pekin ducks kept in groups," *Poultry Science*, vol. 87, no. 2, pp. 215-221, 2008.

[56] B. Hakan and A. Ali, "Effects of light wavelength on broiler performance," *Animal Production*, vol. 46, pp. 22-32, 2005.

[57] P. G. Tickle, J. R. Hutchinson, and J. R. Codd, "Energy allocation and behaviour in the growing broiler chicken," *Scientific Reports*, vol. 8, no. 1, pp. 1-13, 2018.