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Effect of different led light colors and intensities on growth performance and economic outcomes for layers kept in environment-controlled house during brooding phase

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Abstract

Objectives: The study was conducted to determine combined effect of different light colors and intensities on growth performance and economic viability of Babcock® White chicks during brooding phase. **Methods:** Day-old chicks were reared for 8 weeks and divided into 18 treatment groups, each with four replicates of 10 birds. Light treatments of 6 different colors, cool white (control group), red, blue, green, yellow, and warm white light with 3 different levels of light intensities (4, 5 and 6 lux), provided in the brooding. Weekly evaluations for weekly weight, feed intake, body weight, body weight gain, feed conversion ratio, mortality and economic. The data observed was analyzed with Minitab 18. **Results:** Significant effects of different light colors and intensities on weekly weight, feed intake, body weight gain and feed conversion ratio were observed. Highest body weight was observed in birds under warm white light. Red light showed the highest feed intake, meanwhile birds under warm white light combined with 6 lux light intensity demonstrated significantly higher weight gain and efficient feed conversion. Birds under blue light at 4 lux had the lowest production cost (Rs 385.36), while those under warm white light at 6 lux had the highest (Rs 400.68). **Conclusion:** Keeping in view the economic consideration, it can be concluded that during brooding phase any light treatment conducted in these experiments may be applied. However, blue light having 4 lux intensity and warm white light with 6 lux to be the most appropriate choice during brooding phase.

Keywords: Layer; Colors; Intensities; Growth; FCR; Mortality; Economics.

1. Introduction

Lighting plays a critical role in poultry production, serving not only to provide ambient illumination but also to influence the physiological responses, behavior, growth, and reproductive success of the animals (Nasr *et al.*, 2019). It encompasses four primary dimensions: intensity, photoperiod (the duration of light exposure), spectral content (the color of the light), and the light source itself (Sabuncoglu *et al.,* 2018). The transition away from traditional incandescent bulbs towards more energy-efficient alternatives like light-emitting diode (LED) bulbs and compact fluorescent lamps (CFLs) marks a significant shift in the industry. These alternatives offer enhanced luminous efficiency and longer lifespans, important factors in the management of lighting in poultry settings, which includes considerations of photoperiod, intensity, and specific wavelengths of monochromatic light (Remonato *et al.,* 2022). The application of artificial lighting, chosen from the best available sources and tailored in duration and color, is crucial for achieving desired production levels in laying hens. Presently, the use of fluorescent and LED lighting is prevalent in the sector, with evidence suggesting that LEDs, in particular, are superior in terms of production performance and energy consumption (Markou *et al.*, 2010). The increasing costs of energy in poultry production facilities are driving producers to seek strategies for reducing expenses while still upholding high standards of performance and welfare for the birds (Firouzi *et al.,* 2016). This challenge is especially acute in developing countries, where energy availability and cost can significantly impact various aspects of production. Lighting systems, for example, are essential for facilitating feeding activities, maintaining optimal thermal conditions and managing the production cycle of egg-laying birds, contributing substantially to the total energy costs (Kim *et al.,* 2014). Light is one of the most important environmental elements that must be considered in confined poultry houses. The poultry are not only illuminated by light, but their physiological responses, behavior, growth and development, and production performance are all influenced by light (Wei *et al.,* 2020; Parvin *et al.*, 2014; Borille *et al.*, 2015; Olanrewaju *et al.,* 2006). Light is a significant factor in all of these aspects of poultry production. At the moment, light-emitting diodes (LED) are gradually becoming a substitute for conventional incandescent and fluorescent lights for lighting in poultry houses (Li *et al*., 2018; Yang *et al*., 2016). This is due to the fact that LEDs have a high energy efficiency, a long working life, availability in different peak wavelengths, low electricity consumption, and low rearing cost (Liu *et al.,* 2017; Hassan *et al.,* 2014; Hassan *et al.,* 2013; Huber-Eicher *et al.,* 2013; Sultana *et al.,* 2013). According to Wei *et al.* (2020), and Elkomy *et al.* (2019), two of the most important parameters that influence poultry productivity are the quantity (intensity) of light and the quality (color) of light they get. Researchers have found that high light intensity may lead to an increase in poultry activity, feather pecking and cannibalism, as well as sexual development (Nega, 2024; Shi *et al.,* 2019; Renema and Robinson, 2001). Additionally, these researchers have found that increasing light intensity may lead to a reduction in leg disease and improving feeding behavior in poultry (Sun *et al.,* 2023; Ashabranner, 2023). The color of light is determined by the wavelength, and it can have a variety of consequences on the performance of poultry populations. According to Xie *et al.* (2008b), lights of varying wavelengths have a variety of stimulatory effects on the retina, which can lead to behavioral changes that have an impact on the growth and development of chickens. Studies have shown that exposure to blue and green light can increase the growth of layer chickens, aid to calm them down, promote their production performance (Zhang *et al.,* 2014; Hassan *et al.,* 2013; Xie *et al.,* 2008a,b) and improve egg quality (Er *et al.,* 2007). It has been demonstrated that exposure to red light can raise the levels of reproductive hormones, encourage the development of sexual organs, affect the age at which pullets reach sexual maturity (SM) (Hassan *et al.,* 2013; Min *et al.,* 2012; Gongruttananun, 2011), improve production performance (Nega, 2024; Min *et al.,* 2012) and have an effect on feather pecking and cannibalism (Rozenboim *et al.,* 2004).

There are not many studies on combined effect of light color and intensities on brooding performance of layer birds. There this study was conducted to determine the effect of different colors and light intensities on growth performance and economic viability of layer chicks.

2. Materials and Methods

The current study was performed to determine the effect of different LED light colors and intensities on the productive performance of Babcock® commercial layers. The research was conducted at Kamboh Layer Poultry Farm (Hussain Chicks), Tehsil Samundri, District Faisalabad, Pakistan. The experimental duration for this experiment was 8 weeks of brooding phase (0-8 weeks). Lighting schemes mention in (Table 1). Electric dimmer designed to control the intensity of light, and Lux Meter (Measure the intensity of light).

2.1 Experimental Plan

Day-old chicks of the commercial layer Babcock® White strain were divided into 18 treatment groups, which were further distributed into 72 replications under a completely randomized design. Each group consisted of 4 replicates with 10 birds in each; hence, a total of 720 birds were subjected to the experimentation under a 6*3 factorial arrangement as mentioned in Table 1. These birds were kept in an independent, environmentally controlled laying house with the dimensions of 3-tiered laying cages measuring 2 feet × 4 feet × 2 feet and a sloping wire floor. The ventilation, humidity, and house temperature were controlled using side fans and pads. The birds were housed in an environment-controlled facility; however, variations in daily temperature (°F) and humidity (%) were monitored using a wet and dry bulb hygrometer. The temperature was kept constant at 33 °C during the first 3 days and lowered until standard was achieved on day 42. The layer vaccination schedule was followed as mentioned in (Table 2). The chicks were fed a starter mash diet (2900 kcal/kg ME and 21% protein) from 0 to 3 weeks and a grower diet (2750 kcal/kg ME and 19% protein) from 4 to 8 weeks.

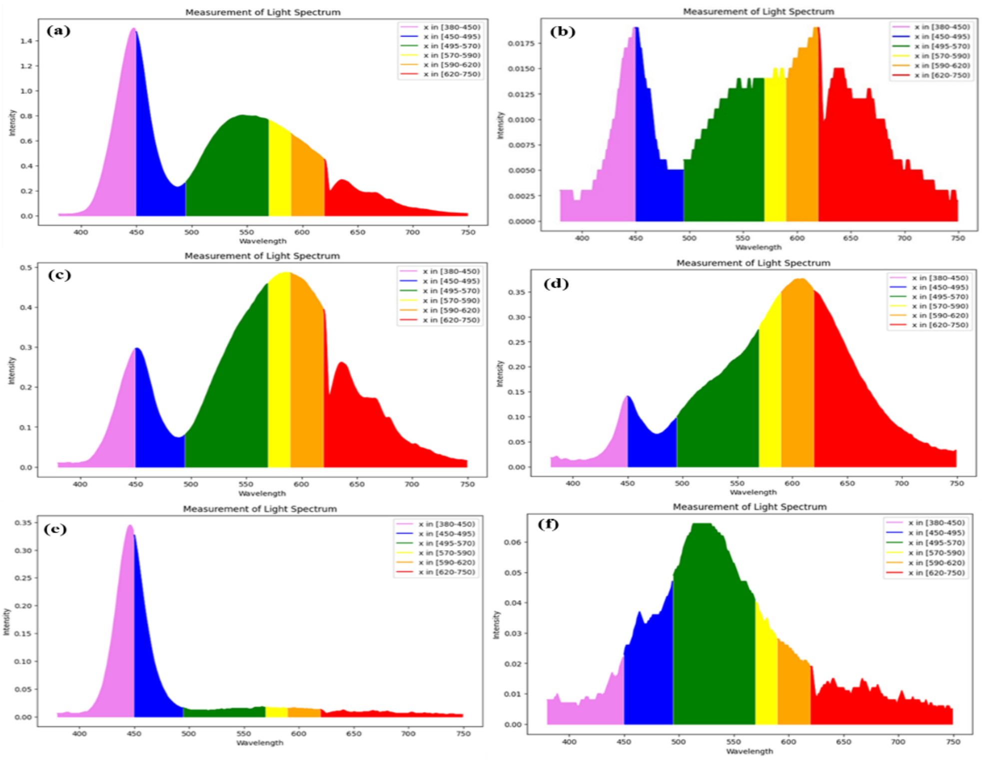

Figure. 1 (a) Light spectrum of cool white Color light (b) Light spectrum of red color light (c) Light spectrum of warm white color light (d) Light spectrum of yellow color light (e) Light spectrum of blue color light (f) Light spectrum of green color light

2.2 Parameters

The effect of different light treatments was determined on body weight gain from 0 to 8 weeks of age. Moreover, production parameters regarding feed intake, body weight, body weight gain, mortality percentage, and FCR were evaluated weekly.

2.3 Estimation of Feed Intake

Weekly feed intake was calculated by subtracting the amount of feed refused from the total feed offered during the week.

$$\text{Feed intake} = \frac{\text{Feed offered} - \text{Feed refusal}}{\text{Number of birds per replicate}}$$

(Nguyen, 2021)

2.4 Determination of Live Body Weight

When chicks arrived at the shed, the body weight of all birds was determined by an electric weighing balance. All 10 birds from each replicate were weighed together, and the mean body weight was calculated.

(Nguyen, 2021)

2.5 Feed Conversion Ratio (FCR)

Feed intake and weight gain were used to calculate FCR by using the following formula.

$$\text{FCR} = \text{Feed intake (g)} / \text{Weight gain (g)}$$

(Mangnale, 2019)

2.6 Mortality

Throughout the experiment, mortality was also calculated.

2.7 Economics

The economics of trial was also calculated at the end of experiment.

2.8 Statistical Analysis

The acquired data were evaluated by CRD with a factorial layout using the GLM technique of SAS (SAS, 2009). Tukey's test proposed by Steel *et al.* (1997) was used for means comparison. The graphical presentation was done by Origin Pro 2024 and RStudio.

Table 1 Experimental design of LED light treatments

Treatment	Color of Lights	Light Intensity (Lux) Experiment-I (0-8 weeks)
1	Cool white (Control)	4
2	Cool white (Control)	5
3	Cool white (Control)	6
4	Red	4
5	Red	5
6	Red	6
7	Blue	4
8	Blue	5
9	Blue	6

10	Green	4
11	Green	5
12	Green	6
13	Yellow	4
14	Yellow	5
15	Yellow	6
16	Warm white	4
17	Warm white	5
18	Warm white	6

Table 2 Vaccination schedule

Age (day)	Vaccine	Route
Day old	Marek's disease	Subcutaneous
5	Newcastle+Infectious Bronchitis	Eye drop
8	Infectious Bursal Disease	Eye drop
18	Infectious Bursal Disease	Drinking water
21	Newcastle disease (LaSota)	Drinking water
32	Infectious Bursal Disease	Drinking water
38	Newcastle disease (LaSota)	Drinking water
49	Fowl pox	Wing web
56 (8 weeks)	Coryza	Subcutaneous

1. Results

3.1 Feed Intake (0-8 weeks)

The results of the experiment showed that color of light, intensity of light and interaction of color and intensity of light significantly ($p<0.05$) affect the feed intake of the birds. The results of feed intake of birds (0-8 weeks) are given in (Table 3). Significantly highest feed intake was observed in the birds kept under blue color light having 5 lux intensity, yellow color having 4, 5, 6 lux intensity, Green color having 6 lux intensity, Green having 6 lux intensity, red color having 5 lux intensity, Yellow color having 6 lux intensity, red color having 4 lux intensity and red color having 5 lux intensity at 1st , 2nd, 3rd , 4th , 5th, 6th , 7th and 8th weeks of age respectively (Table 3). However, significantly highest overall feed intake (1620 g per bird) was observed in the birds kept under blue light having 6 lux light intensity.

Table 3 Effect of color and intensity of light on weekly feed intake of birds (0-8 weeks)

Treatments	Feed intake (g)							
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
Main effect (light colors)								
Cool white	64.04^{b}	106.25^{b}	151.33^{b}	190.83^{b}	212.58^{e}	253.75^{d}	281.33^{b}	317.50^{b}
Red	68.37^{a}	95.67^{c}	147.83^{c}	176.00^{c}	232.83^{a}	265.92^{a}	290.42^{a}	322.83^{a}
Blue	68.04^{a}	105.33^{b}	151.17^{b}	201.00^{a}	215.58^{d}	251.33^{d}	278.08^{c}	314.50^{c}
Green	67.95^{a}	105.50^{b}	153.50^{a}	197.00^{a}	214.67^{de}	251.50^{d}	281.08^{b}	311.00^{cd}
Yellow	68.45^{a}	108.33^{a}	150.83^{b}	188.25^{b}	219.08^{c}	259.75^{c}	281.25^{b}	311.58^{cd}
Warm white	68.95^{a}	95.67^{c}	145.67^{d}	165.75^{d}	222.25^{b}	262.25^{b}	279.08^{bc}	309.75^{d}

SEM	±0.32	±0.43	±0.51	±1.20	±0.57	±0.59	±0.66	±0.70
Main effect (light intensity)								
4 lux	66.91^{b}	101.50^{b}	150.83^{a}	186.92^{a}	218.33^{b}	256.00^{b}	280.63^{b}	311.33^{b}
5 lux	67.70^{a}	103.63^{a}	148.04^{b}	186.38^{a}	218.38^{b}	254.58^{b}	282.25^{a}	315.29^{a}
6 lux	68.29^{a}	103.25^{a}	151.29^{a}	186.13^{a}	221.79^{a}	261.67^{a}	282.75^{a}	316.96^{a}
SEM	±0.22	±0.30	±0.36	±0.84	±0.40	±0.42	±0.47	±0.49
Interaction (light colors intensity)*								
Cool white-4 lux	63.75^{e}	103.75^{bc}	148.00^{cde}	191.00^{bcd}	211.00^{ghi}	256.25^{def}	281.50^{cde}	310.25^{ef}
Cool white-5 lux	64.25^{de}	107.50^{ab}	150.75^{bcd}	190.50^{bcd}	208.00^{i}	253.50^{efg}	281.25^{cde}	314.50^{e}
Cool white-6 lux	64.12^{de}	107.50^{ab}	155.25^{ab}	191.00^{bcd}	218.75^{cde}	251.50^{fg}	282.50^{cde}	327.75^{ab}
Red-4	69.00^{ab}	96.25^{de}	146.25^{de}	181.75^{de}	233.25^{b}	266.50^{ab}	293.50^{a}	322.75^{bc}
Red-5	66.75^{bcd}	95.75^{de}	148.50^{cde}	176.25^{ef}	245.25^{a}	266.00^{ab}	291.50^{ab}	330.75^{a}
Red-6	69.37^{ab}	95.00^{de}	148.75^{cde}	170.00^{fg}	220.00^{cde}	265.25^{ab}	286.25^{bc}	315.00^{de}
Blue-4	65.37^{cde}	104.00^{bc}	152.25^{bc}	200.25^{ab}	212.50^{ghi}	248.75^{gh}	270.75^{f}	309.50^{ef}
Blue-5	69.12^{ab}	106.00^{abc}	148.75^{cde}	199.00^{ab}	212.00^{ghi}	243.50^{hi}	280.50^{cde}	312.75^{e}
Blue-6	69.62^{a}	106.00^{abc}	152.50^{bc}	203.75^{a}	222.25^{cd}	261.75^{bc}	283.00^{cde}	321.25^{cd}
Green-4	67.12^{abc}	103.50^{c}	153.50^{b}	192.00^{bcd}	213.25^{fgh}	251.50^{fg}	280.00^{de}	309.50^{ef}
Green-5	68.25^{ab}	106.75^{abc}	148.50^{cde}	195.25^{abc}	208.50^{hi}	241.75^{i}	279.25^{de}	309.25^{ef}
Green-6	68.50^{ab}	106.25^{abc}	158.50^{a}	203.75^{a}	222.25^{cd}	261.25^{bcd}	284.00^{cd}	314.25^{e}
Yellow-4	67.37^{abc}	108.25^{a}	150.75^{bcd}	187.25^{cd}	217.75^{def}	253.75^{efg}	280.75^{cde}	309.75^{ef}
Yellow-5	69.00^{ab}	108.25^{a}	147.25^{de}	190.50^{bcd}	215.75^{efg}	258.25^{cde}	281.25^{cde}	313.50^{e}
Yellow-6	69.00^{ab}	108.50^{a}	154.50^{ab}	187.00^{cde}	223.75^{c}	267.25^{a}	281.75^{cde}	311.50^{ef}
Warm white-4	68.87^{ab}	93.25^{e}	154.25^{ab}	169.25^{fg}	222.25^{cd}	259.25^{cd}	277.25^{e}	306.25^{f}
Warm white-5	68.87^{ab}	97.50^{d}	144.50^{e}	166.75fg	220.75^{cde}	265.25^{ab}	281.00^{cde}	311.00^{ef}
Warm white-6	69.12^{ab}	96.25^{de}	138.25^{f}	161.25^{g}	223.75^{c}	262.25^{abc}	279.00^{de}	312.00^{ef}
SEM	±0.55	±0.75	±0.89	±2.07	±1.00	±1.03	±1.15	±1.21
Level of significance								
Light colors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light intensity	0.00	0.00	0.00	0.79	0.00	0.00	0.00	0.00
Interaction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

^{a,b,c,d} Values within a column with different superscript are significantly different (P<0.05). Data are presented as mean±SEM.

3.2 Body Weight (0-8 weeks)

The results of the experiment demonstrated that color of light, intensity of light and interaction of color and intensity of light significantly (p<0.05) affect the body weight of the birds. The weekly body weight data, summarized in (Table 4), indicate significant (p<0.05) differences across treatments. Throughout the eight weeks, birds exposed to warm white light at 6 lux showed the highest mean weekly weights, significantly outperforming those under other light colors (white, red, blue, green, and yellow). By the end of week eight, warm white light produced a body weight of 643.58 g, which was significantly (p<0.05) higher than the weights under other lighting conditions. There were also significant differences in body weights based on light intensity, with 5 lux generally resulting in higher weights compared to 4 lux and 6 lux. The interaction between light colors and intensities also revealed significant (p<0.05) differences in body weights. The analysis of variance confirms significant effects of light intensity and color on weekly weight gain, as well as their interaction, indicating a complex influence of these factors on growth. Although green light did not considerably surpass the performance of warm white and blue light, its difference was significantly (p<0.05) different with a mean value of 566.38 g.

Table 4 Effect of LED light color and intensity on weekly weight (g) of layers (0-8 weeks)

Treatments	Body Weight (g)							
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week

Main effect (light colors)								
Cool White	58.58^{bc}	108.58^{b}	179.25^{b}	267.92^{b}	357.25^{b}	440.83^{b}	518.33^{b}	604.17^{b}
Red	55.25^{d}	99.92^{c}	165.42^{e}	240.75^{d}	322.92^{d}	398.58^{e}	474.75^{e}	557.00^{e}
Blue	59.08^{b}	108.25^{b}	176.42^{c}	271.75^{a}	357.00^{b}	439.92^{b}	517.17^{bc}	601.83^{bc}
Green	58.37^{bc}	107.83^{b}	174.54^{d}	264.75^{c}	351.50^{c}	436.50^{c}	515.42^{cd}	600.17^{cd}
Yellow	58.00^{c}	108.83^{b}	177.50^{c}	264.50^{c}	350.92^{c}	434.17^{d}	513.33^{d}	598.92^{d}
Warm white	61.79^{a}	111.50^{a}	186.58^{a}	270.75^{a}	376.33^{a}	471.42^{a}	554.08^{a}	643.58^{a}
SEM	±0.22	±0.27	±0.31	±0.45	±0.44	±0.47	±0.53	±0.60
Main effect (light intensity)								
4 lux	58.14^{b}	107.75^{a}	176.52^{b}	262.75^{b}	351.29^{b}	434.00^{b}	511.92^{b}	596.04^{b}
5 lux	58.58^{ab}	107.75^{a}	177.33^{a}	266.13^{a}	356.67^{a}	441.71^{a}	522.21^{a}	609.67^{a}
6 lux	58.81^{a}	106.96^{b}	176.00^{b}	261.33^{c}	350.00^{c}	435.00^{b}	512.42^{b}	597.13^{b}
SEM	±0.16	±0.19	±0.22	±0.32	±0.31	±0.33	±0.38	±0.42
Interaction (light colors intensity)*								
Cool white-4 lux	57.62e	108.25^{def}	177.75^{ef}	266.50^{cd}	356.75^{ef}	441.00^{de}	517.50^{ef}	600.50^{g}
Cool white-5 lux	59.12^{cde}	108.75^{cde}	181.25^{cd}	273.00^{b}	364.25^{c}	450.50^{c}	531.00^{c}	619.75^{c}
Cool white-6 lux	59.00^{de}	108.75^{cde}	178.75^{de}	264.25^{de}	350.75^{g}	431.00^{gh}	506.50^{g}	592.25^{ij}
Red-4 lux	55.37^{fg}	102.00^{g}	168.75^{i}	249.50^{g}	334.50^{i}	414.25^{i}	494.25^{h}	579.75^{k}
Red-5 lux	55.50^{fg}	100.25^{g}	166.00^{i}	240.75^{h}	327.25^{j}	402.00^{j}	477.75^{i}	561.25^{l}
Red-6 lux	54.87^{g}	97.50^{h}	161.50^{j}	232.00^{i}	307.00^{k}	379.50^{k}	452.25^{j}	530.00^{m}
Blue-4 lux	58.75^{d}	109.25^{cd}	177.25^{efg}	271.25^{b}	356.25^{ef}	434.75^{fg}	509.50^{g}	591.75^{ij}
Blue-5 lux	59.75^{bcd}	109.00^{cd}	177.50^{ef}	274.00^{ab}	359.75^{de}	444.50^{d}	525.50^{d}	614.00^{de}
Blue-6 lux	58.75^{de}	106.50^{ef}	174.50^{gh}	270.00^{bc}	355.00^{f}	440.50^{de}	516.50^{f}	599.75^{gh}
Green-4 lux	58.37^{de}	109.25^{cd}	175.63^{fgh}	261.75^{ef}	348.75^{g}	431.50^{gh}	508.00^{g}	590.50^{ij}
Green-5 lux	58.00^{de}	108.00^{def}	173.50^{h}	267.00^{cd}	356.25^{ef}	440.75^{de}	521.50^{de}	607.75^{f}
Green-6 lux	58.75^{de}	106.25^{f}	174.50^{gh}	265.50^{de}	349.50^{g}	437.25^{ef}	516.75^{ef}	602.25^{g}
Yellow-4 lux	57.62^{e}	110.75^{bc}	177.50^{ef}	264.00^{de}	349.50^{g}	430.25^{h}	509.50^{g}	595.00^{hi}
Yellow-5 lux	57.37^{ef}	108.00^{def}	179.50^{cde}	270.50^{bc}	358.50^{def}	442.25^{d}	523.75^{d}	612.25^{ef}
Yellow-6 lux	59.00^{de}	107.75^{def}	175.50^{fgh}	259.00^{f}	344.75^{h}	430.00^{h}	506.75^{g}	589.50^{j}
Warm white-4 lux	61.12^{abc}	107.00^{def}	182.25^{c}	263.50^{de}	362.00^{cd}	452.25^{c}	532.75^{c}	618.75^{cd}
Warm white-5 lux	61.75^{ab}	112.50^{b}	186.25^{b}	271.50^{b}	374.00^{b}	470.25^{b}	553.75^{b}	643.00^{b}
Warm white-6 lux	62.50^{a}	115.00^{a}	191.25^{a}	277.25^{a}	393.00^{a}	491.75^{a}	575.75^{a}	669.00^{a}
SEM	±0.39	±0.47	±0.54	±0.78	±0.77	±0.81	±0.93	±1.05
Level of significance								
Light colors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light intensity	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Interaction	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00

^{a,b,c,d} Values within a column with different superscript are significantly different (P<0.05). Data are presented as mean±SEM.

3.3 Weekly Weight Gain (0-8 weeks)

The results of the experiment showed that color of light, intensity of light and interaction of color and intensity of light significantly (p<0.05) affect the body weight gain of the birds (Table 5). These results indicate that warm white light, most effectively supported weight gain (p<0.05) throughout each of the weeks, culminating in an 89.50 g gain in the eighth week with 6 lux light intensity. Red light with all three light intensities 4, 5 and 6 lux, conversely, resulted in the numerically lowest weight gain, which is especially noticeable in the intermediate weeks; in combination, these gain outcomes invariably majorly underperformed compared to those with warm white light as shown in (Table 5). Additionally, blue and green lights demonstrated intermediate performance with some peaks, reflecting variable but noteworthy weight gains across different phases. It is note worth noting that blue light with 5 lux light intensity combination showed highest weight gain of 96.50 g at 4th week age (Table 5).

Table 5 Effect of light color and intensity on weekly weight gain (g) of layers (0-8 weeks)

Treatments	Weight gain (g)							
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
Main effect (light colors)								

Cool white	17.70^{b}	50.00^{ab}	70.66^{b}	88.66^{bc}	89.33^{b}	83.58^{c}	77.50^{c}	85.83^{b}
Red	14.41^{c}	44.66^{c}	65.50^{e}	75.33^{e}	82.17^{e}	75.66^{d}	76.16^{d}	82.25^{e}
Blue	17.87^{b}	49.16^{b}	68.16^{c}	95.33^{a}	85.25^{d}	82.91^{c}	77.25^{c}	84.66^{d}
Green	17.25^{b}	49.45^{b}	66.70^{d}	90.20^{b}	86.75^{c}	85.00^{b}	78.91^{b}	84.75^{cd}
Yellow	16.95^{b}	50.83^{a}	68.66^{c}	87.00^{c}	86.42^{cd}	83.25^{c}	79.16^{b}	85.58^{bc}
Warm white	20.50^{a}	49.70^{b}	75.08^{a}	84.16^{d}	105.58^{a}	95.08^{a}	82.66^{a}	89.50^{a}
SEM	±0.20	±0.15	±0.18	±0.33	±0.20	±0.17	±0.15	±0.15
Main effect (light intensity)								
4 lux	17.27	49.60^{a}	68.77^{b}	86.22^{b}	88.54^{b}	82.70^{b}	77.91^{b}	84.12^{c}
5 lux	17.35	49.16^{a}	69.58^{a}	88.79^{a}	90.54^{a}	85.042^{a}	80.50^{a}	87.45^{a}
6 lux	17.72	48.14^{b}	69.04^{ab}	85.33^{b}	88.66^{b}	85.00^{a}	77.41^{b}	84.70^{b}
SEM	±0.29	±0.21	±0.25	±0.46	±0.29	±0.24	±0.22	±0.21
Interaction (light colors intensity)*								
Cool white-4 lux	17.25^{cd}	50.62^{bcd}	69.50^{de}	88.75^{de}	90.25^{de}	84.25^{efg}	76.50^{e}	83.00^{d}
Cool white-5 lux	18.12^{bc}	49.62^{cde}	72.50^{c}	91.75^{bcd}	91.25^{d}	86.25^{de}	80.50^{cd}	88.75^{b}
Cool white-6 lux	17.75^{bcd}	49.75^{cd}	70.00^{de}	85.50^{ef}	86.50^{ghi}	80.25^{ij}	75.50^{e}	85.75^{c}
Red-4 lux	14.25^{e}	46.62^{gh}	66.75^{fgh}	80.75^{h}	85.00^{hi}	79.75^{ij}	80.00^{cd}	85.50^{c}
Red-5 lux	15.25^{def}	44.75^{h}	65.75^{ghi}	74.75^{i}	86.50^{ghi}	74.75^{k}	75.75^{e}	83.50^{d}
Red-6 lux	13.75^{f}	42.62^{i}	64.00^{i}	70.50^{j}	75.00^{j}	72.50^{l}	72.75^{f}	83.25^{d}
Blue-4 lux	18.00^{bc}	50.50^{cd}	68.00^{efg}	94.00^{abc}	85.00^{hi}	78.50^{j}	74.75^{ef}	82.25^{d}
Blue-5 lux	18.00^{bc}	49.25^{cdef}	68.50^{ef}	96.50^{a}	85.75^{ghi}	84.75^{efg}	81.00^{cd}	88.50^{b}
Blue-6 lux	17.62^{bcd}	47.75^{efg}	68.00^{efg}	95.50^{ab}	85.00^{hi}	85.50^{ef}	76.00^{e}	77.75^{e}
Green-4 lux	17.37^{cd}	50.87^{bc}	66.37^{fgh}	86.12^{ef}	87.00^{fgh}	82.75^{gh}	76.50^{e}	82.50^{d}
Green-5 lux	16.62^{cde}	50.00^{cd}	65.50h^{i}	86.12^{ef}	89.25^{def}	84.50^{efg}	80.75^{cd}	86.25^{c}
Green-6 lux	17.75^{bcd}	47.50^{fg}	68.25^{ef}	91.00^{cd}	84.00^{i}	87.75^{d}	79.50^{cd}	85.50^{c}
Yellow-4 lux	16.75^{cde}	53.12^{a}	66.75^{fgh}	86.50^{ef}	85.50^{ghi}	80.75^{hi}	79.25^{d}	85.50^{c}
Yellow-5 lux	16.00^{cdef}	50.62^{bcd}	71.50^{cd}	91.00^{cd}	88.00^{efg}	83.75^{fg}	81.50^{bc}	88.50^{b}
Yellow-6 lux	18.12^{bc}	48.75^{def}	67.75^{efgh}	83.50^{fgh}	85.75^{ghi}	85.25^{ef}	79.25^{d}	82.75^{d}
Warm white-4 lux	20.00^{ab}	45.87^{gh}	75.25^{ab}	81.25^{gh}	98.50^{c}	90.25^{c}	80.50^{cd}	86.00^{c}
Warm white-5 lux	20.12^{ab}	50.75^{bc}	73.75^{bc}	85.25^{efg}	102.50^{b}	96.25^{b}	83.50^{ab}	89.25^{b}
Warm white-6 lux	21.37^{a}	52.50^{ab}	76.25^{a}	86.00^{ef}	115.75^{a}	98.75^{a}	84.00^{a}	93.25^{a}
SEM	±0.50	±0.36	±0.44	±0.81	±0.50	±0.42	±0.38	±0.37
Level of significance								
Light colors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light intensity	0.25	0.00	0.09	0.00	0.00	0.00	0.00	0.00
Interaction	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00

^{a,b,c,d} Values within a column with different superscript are significantly different (P<0.05). Data are presented as mean±SEM.

3.4 Feed Conversion Ratio (FCR)

The effects of light color and intensity and interaction of light color and intensity on the feed conversion ratio (FCR) of layers over a period of eight weeks, as well as cumulative FCR changes over three phases are also observed in this experiment (Table 6). The weekly FCR found to be significant (p<0.05) among all treatment groups specially for interaction of light colors and intensities. The weekly FCR values for different light colors differ significantly. Warm white color with 6 lux light intensity demonstrated the efficient FCR values overall, which became most notable in the later weeks, with several values approaching as little as 3.34 in the eighth week. Moreover, red color light with 6 lux light intensity was the least efficient light in maintaining FCR, with the highest weekly value of 4.05 in the final week.

Table 6 Effect of light color and intensity on weekly feed conversion ratio of layers (0-8 weeks)

Treatments	FCR							
	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week
Main effect (light colors)								
Cool white	3.62^{cd}	2.12^{a}	2.14^{d}	2.15^{b}	2.38^{d}	3.03^{c}	3.63^{b}	3.70^{b}

Red	4.76^{a}	2.14^{a}	2.25^{b}	2.34^{a}	2.83^{a}	3.52^{a}	3.81^{a}	3.92^{a}
Blue	3.81^{bc}	2.14^{a}	2.21^{c}	2.10^{c}	2.53^{b}	3.03^{c}	3.60^{b}	3.71^{b}
Green	3.95^{b}	2.13^{a}	2.30^{a}	2.18^{b}	2.47^{c}	2.96^{d}	3.56^{c}	3.67^{c}
Yellow	4.06^{b}	2.13^{a}	2.19^{c}	2.16^{b}	2.53^{b}	3.12^{b}	3.55^{c}	3.64^{c}
Warm white	3.37^{d}	1.92^{b}	1.94^{e}	1.97^{d}	2.11^{e}	2.76^{e}	3.37^{d}	3.46^{d}
SEM	±0.066	±0.006	±0.007	±0.008	±0.007	±0.006	±0.007	±0.006
Main effect (light intensity)								
4 lux	3.92	2.04^{c}	2.19^{a}	2.16^{a}	2.47^{b}	3.10^{a}	3.60^{b}	3.70^{b}
5 lux	3.94	2.10^{b}	2.13^{b}	2.10^{b}	2.42^{c}	3.01^{b}	3.51^{c}	3.60^{c}
6 lux	3.92	2.15^{a}	2.19^{a}	2.18^{a}	2.54^{a}	3.10^{a}	3.66^{a}	3.75^{a}
SEM	±0.047	±0.004	±0.004	±0.006	±0.005	±0.004	±0.005	±0.004
Interaction (light colors intensity)*								
Cool white-4 lux	3.69^{defg}	2.05^{e}	2.13^{fg}	2.15^{def}	2.33^{i}	3.04^{fg}	3.68^{cde}	3.73^{e}
Cool white-5 lux	3.56^{defg}	2.16^{bcd}	2.08^{gh}	2.07^{fg}	2.27^{ij}	2.94^{h}	3.47^{hi}	3.54^{h}
Cool white-6 lux	3.62^{defg}	2.16^{cd}	2.21^{cde}	2.23^{bcd}	2.53^{fg}	3.13^{de}	3.74^{c}	3.82^{cd}
Red-4 lux	4.85^{ab}	2.06^{e}	2.19^{def}	2.25^{b}	2.74^{c}	3.34^{c}	3.66^{de}	3.77^{de}
Red-5 lux	4.38^{bc}	2.14^{d}	2.25^{bc}	2.35^{a}	2.83^{b}	3.54^{b}	3.85^{b}	3.96^{b}
Red-6 lux	5.06^{a}	2.22^{a}	2.32^{a}	2.41^{a}	2.93^{a}	3.67^{a}	3.93^{a}	4.05^{a}
Blue-4 lux	3.65^{defg}	2.06^{e}	2.24^{cd}	2.13^{efg}	2.50^{fgh}	3.16^{d}	3.62^{ef}	3.76^{e}
Blue-5 lux	3.84^{cdef}	2.15^{d}	2.17^{ef}	2.06^{g}	2.47^{gh}	2.87^{i}	3.46^{i}	3.53^{hi}
Blue-6 lux	3.95^{cdef}	2.22^{abc}	2.24^{cd}	2.13^{efg}	2.61^{de}	3.06^{f}	3.72^{cd}	3.86^{c}
Green-4 lux	3.88^{cdef}	2.03^{e}	2.31^{ab}	2.23^{bcd}	2.45^{h}	3.04^{fg}	3.66^{de}	3.75^{e}
Green-5 lux	4.12^{cd}	2.13^{d}	2.26^{abc}	2.08^{efg}	2.34^{i}	2.86^{i}	3.46^{i}	3.58^{gh}
Green-6 lux	3.87^{cdef}	2.23^{a}	2.32^{a}	2.23^{bc}	2.64^{d}	2.98^{gh}	3.57^{fg}	3.67^{f}
Yellow-4 lux	4.03^{cde}	2.04^{e}	2.25^{bc}	2.16^{cde}	2.54^{ef}	3.14^{de}	3.54^{gh}	3.62^{fg}
Yellow-5 lux	4.33^{bc}	2.14^{d}	2.06^{h}	2.09^{efg}	2.45^{h}	3.08^{ef}	3.45^{i}	3.54^{h}
Yellow-6 lux	3.81^{cdefg}	2.22^{ab}	2.27^{abc}	2.24^{bc}	2.61^{de}	3.13^{de}	3.67^{de}	3.76^{de}
Warm white-4 lux	3.45^{efg}	2.03^{e}	2.05^{h}	2.08^{fg}	2.25^{j}	2.87^{i}	3.44^{i}	3.56^{h}
Warm white-5 lux	3.42^{fg}	1.92^{f}	1.96^{i}	1.95^{h}	2.15^{k}	2.75^{j}	3.36^{j}	3.48^{i}
Warm white-6 lux	3.23^{g}	1.83^{g}	1.81^{j}	1.87^{i}	1.93^{l}	2.65^{k}	3.32^{j}	3.34^{j}
SEM	±0.115	±0.011	±0.012	±0.015	±0.013	±0.011	±0.013	±0.011
Level of significance								
Light colors	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light intensity	0.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Interaction	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

^{a,b,c,d} Values within a column with different superscript are significantly different ($P<0.05$). Data are presented as mean±SEM.

3.5 Mortality

This study also examined the effect of different light colors and intensities and interaction of light color and intensity on the mortality rates of layers over an eight-week period. It was found that there was no significant ($p>0.05$) influence of light colors and intensities on mortality of layers (Table 7). Numerically warm white light demonstrated the lowest overall mortality, particularly noticeable with a total eight-week mortality rate of mean 0.42. In contrast, red light exhibited the highest mortality rates, culminating in a total of mean 1.00 in conditions combined with certain light intensities (5 lux and 6 lux). The other light colors showed intermediate mortality rates, with blue and yellow lights associated with comparatively lower mortality figures similar to those under warm white light.

Table 7 Effect of light color and intensity on mortality in layers

Treatments	Mortality of birds		
	First Four weeks	Last four week	Total eight week
Main effect (light colors)			
Cool white	0.50	0.08	0.58
Red	0.75	0.17	0.92
Blue	0.58	0.00	0.58
Green	0.58	0.08	0.67
Yellow	0.50	0.00	0.50

Warm white	0.33	0.08	0.42
SEM	±0.15	±0.07	±0.14
Main effect (light intensity)			
4 lux	0.50	0.04	0.54
5 lux	0.54	0.04	0.58
6 lux	0.58	0.13	0.71
SEM	±0.10	±0.05	±0.10
Interaction (light colors intensity)*			
Cool white-4 lux	0.75	0.00	0.75
Cool white-5 lux	0.25	0.25	0.50
Cool white-6 lux	0.50	0.00	0.50
Red-4 lux	0.50	0.25	0.75
Red-5 lux	1.00	0.00	1.00
Red-6 lux	0.75	0.25	1.00
Blue-4 lux	0.50	0.00	0.50
Blue-5 lux	0.50	0.00	0.50
Blue-6 lux	0.75	0.00	0.75
Green-4 lux	0.50	0.00	0.50
Green-5 lux	0.75	0.00	0.75
Green-6 lux	0.50	0.25	0.75
Yellow-4 lux	0.25	0.00	0.25
Yellow-5 lux	0.50	0.00	0.50
Yellow-6 lux	0.75	0.00	0.75
Warm white-4 lux	0.50	0.00	0.50
Warm white-5 lux	0.25	0.00	0.25
Warm white-6 lux	0.25	0.25	0.50
SEM	±0.26	±0.13	±0.25
Level of significance			
Light colors	0.85	0.64	0.24
Light intensity	0.53	0.45	0.50
Interaction	0.71	0.62	0.95

[a,b,c,d] Values within a column with different superscript are significantly different (P<0.05). Data are presented as mean±SEM.

3.6 Economics of the Experiment (0-8 weeks)

In the present study on the economics of rearing layers were also observed under different light color and light intensity (Table 8). The results of the experiment showed that color of light, intensity of light and interaction of color and intensity of light did not significantly affect the cost of production of the birds at 8th weeks of age. However apparently lowest (Rs: 385.36) cost of production was observed in the birds kept under blue light having 4 lux light intensity and highest (Rs: 400.68) cost of production was observed in the birds kept under warm white light having 6 lux intensity.

Table 8 Effect of color and intensity of light on economic of layers (0-8 weeks)

Treatments	Economics								
	Cost of per chicks	Cost of light treatment	Total feed Intake (kg/bird)	Cost of Feed (per kg/birds)	Weight of bird (kg/birds)	Cost of feed per bird	Mortality	Cost of mortality per birds	Cost of production per bird (0-8 weeks)
Main effect (light colors)									
Cool white	160	3.73^{a}	1.50^{c}	216.44^{c}	0.60^{b}	130.75^{bc}	0.58	14.4	392.3
Red	160	3.73^{a}	1.52^{a}	220.25^{a}	0.55^{e}	122.72^{d}	0.91	22.64	392.51
Blue	160	3.73^{a}	1.49^{c}	215.91^{c}	0.60^{bc}	129.94^{bc}	0.58	14.4	391.49
Green	160	3.73^{a}	1.50^{c}	216.10^{c}	0.60^{cd}	129.70^{c}	0.66	16.46	393.3
Yellow	160	3.73^{a}	1.51^{b}	218.54^{b}	0.59^{d}	130.88^{b}	0.5	12.35	390.36
Warm white	160	1.78^{b}	1.48^{d}	214.46^{d}	0.64^{a}	138.03^{a}	0.41	10.2	393.42
SEM		±0.00	±0.002	±0.3	±0.00	±0.26	±0.14	±3.60	±3.60
Main effect (light intensity)									
4 lux	160	3.45	1.49^{c}	215.57^{c}	0.59^{b}	128.47^{c}	0.54	13.36	388.65
5 lux	160	3.45	1.50^{b}	216.50^{b}	0.60^{a}	131.93^{a}	0.58	14.4	393.15
6 lux	160	3.45	1.51^{a}	218.77^{a}	0.59^{b}	130.60^{b}	0.7	17.47	394.89
SEM		±0.00	±0.001	±0.21	±0.00	±0.19	±0.10	±2.50	±2.50
Interaction (light colors intensity)*									
Cool white-4 lux	160	3.73^{a}	1.48^{efgh}	214.31^{efgh}	0.60^{g}	128.69^{fg}	0.75	18.52	394.36
Cool white-5 lux	160	3.73^{a}	1.49^{defg}	215.42^{defg}	0.61^{c}	133.51^{c}	0.5	12.35	393
Cool white-6 lux	160	3.73^{a}	1.52^{bc}	219.58^{bc}	0.59^{ij}	130.05^{def}	0.5	12.35	389.53

Red-4 lux	160	3.73^{a}	1.53^{ab}	220.86^{ab}	0.57^{k}	128.04^{fgh}	0.75	18.52	393.71
Red-5 lux	160	3.73^{a}	1.54^{a}	223.13^{a}	0.56^{l}	125.23^{i}	1	24.7	397.07
Red-6 lux	160	3.73^{a}	1.50^{def}	216.77^{def}	0.53^{m}	114.89^{j}	1	24.7	386.74
Blue-4 lux	160	3.73^{a}	1.47^{h}	212.71^{h}	0.59^{ij}	125.87^{hi}	0.5	12.35	385.36
Blue-5 lux	160	3.73^{a}	1.48^{efgh}	214.36^{efgh}	0.61^{de}	131.62^{cde}	0.5	12.35	391.1
Blue-6 lux	160	3.73^{a}	1.53^{ab}	220.66^{ab}	0.59^{gh}	132.34^{cd}	0.75	18.52	398.01
Green-4 lux	160	3.73^{a}	1.49^{efgh}	214.83^{efgh}	0.59^{ij}	126.86^{ghi}	0.5	12.35	386.35
Green-5 lux	160	3.73^{a}	1.47^{gh}	212.98^{gh}	0.60^{f}	129.44^{ef}	0.75	18.52	395.1
Green-6 lux	160	3.73^{a}	1.53^{ab}	220.50^{ab}	0.60^{g}	132.80^{c}	0.75	18.52	398.46
Yellow-4 lux	160	3.73^{a}	1.50^{cde}	216.95^{cde}	0.59^{hi}	129.09^{fg}	0.25	6.17	382.4
Yellow-5 lux	160	3.73^{a}	1.51^{cd}	217.66^{cd}	0.61^{ef}	133.26^{c}	0.5	12.35	392.75
Yellow-6 lux	160	3.73^{a}	1.53^{ab}	221.00^{ab}	0.58^{j}	130.29^{def}	0.75	18.52	395.95
Warm white-4 lux	160	1.78^{b}	1.48^{gh}	213.79^{gh}	0.61^{cd}	132.28^{cd}	0.5	12.25	389.72
Warm white-5 lux	160	1.78^{b}	1.496^{defg}	215.48^{defg}	0.64^{b}	138.55^{b}	0.25	6.12	389.86
Warm white-6 lux	160	1.78^{b}	1.48^{fgh}	214.11^{fgh}	0.66^{a}	143.24^{a}	0.5	12.25	400.68
SEM		±0.00	±0.003	±0.52	±0.003	±0.46	±0.25	±6.2	±6.3
Level of significance									
Light colors		0	0	0	0	0	0.24	0.24	0.99
Light intensity		1	0	0	0	0	0.5	0.5	0.22
Interaction		0	0	0	0	0	0.95	0.95	0.71

[a,b,c,d] Values within a column with different superscript are significantly different ($P<0.05$). Data are presented as mean±SEM.

3.7 Analysis of Correlation and Heat-Map

The Analysis of Pearson correlation was done across the various growthy attributes of layers birds under the influence of different colors and intensity (Figure 2). The feed intake during the period of 0-8 weeks shows strong positive correlation with the economics. The mortality and FCR (Feed conversion ratio) in the time duration of 0-8 weeks shows slight positive correlation while body weight and weight gain slightly negative correlation with all above mentioned attributes.

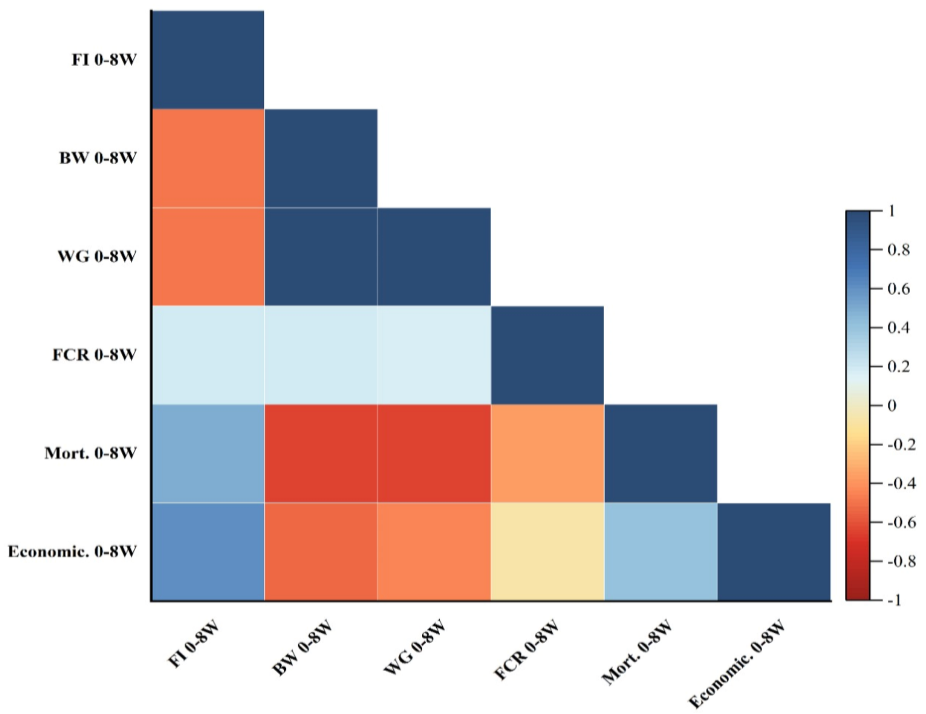

Figure. 2 Analysis of Correlation among the growth parameters under the different color and intensities (0-8 weeks). Feed Intake (FI), Body weight (BW), Weight gain (WG), Feed conversion ratio (FCR), Mortality (Mort.) Economics of the Experiment (Economic).

The heat-map was created across the various growthy attributes of layers birds under the influence of different colors and intensity (Figure 3 and 4). The highest enhancement was observed in the body weight and weight gain in the treatment of warm white having 6 lux light intensity while a significant reduction of these attributes in the treatment of red-6 lux. The feed intake, mortality and economics attributes positively improve while FCR reduce in the treatment of red color having 5 lux light intensity.

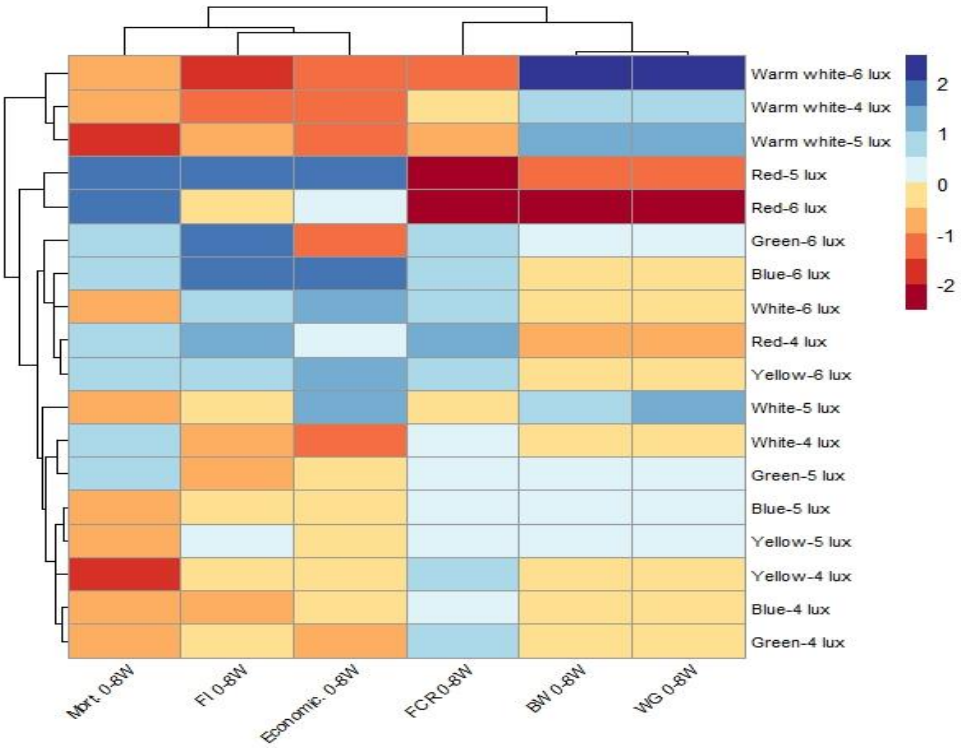

Figure. 3 Heatmap among the growth parameters under the different color and intensities (0-8 weeks). Feed Intake (FI), Body weight (BW), Weight gain (WG), Feed conversion ratio (FCR), Mortality (Mort.) Economics of the Experiment (Economic).

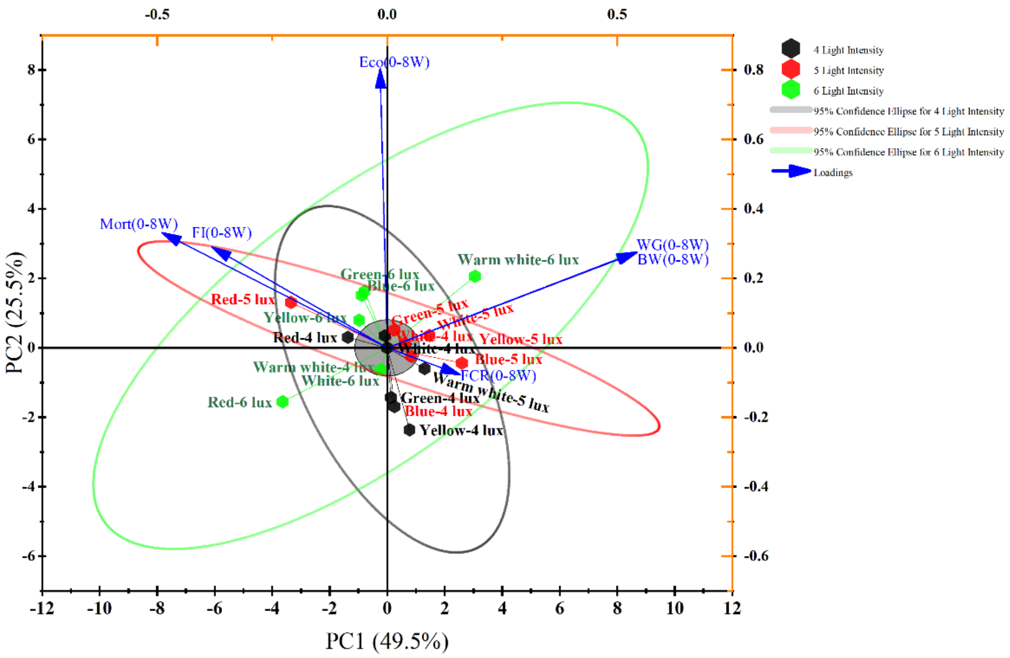

Figure. 4 Principal component analysis among the growth parameters under different color and intensities (0-8 weeks). Feed Intake (FI), Body weight (BW), Weight gain (WG), Feed conversion ratio (FCR), Mortality (Mort.) Economics of the Experiment (Economic).

The chord diagram in (Figure 5) the relationships among various growth parameters under different light colors and intensities during the brooding phase (0-8 weeks). Each node around the circumference represents distinct growth parameters and treatment groups. The interconnecting chords depict the interactions between these parameters, with the thickness of the chords indicating the strength and significance of these interactions. The diagram demonstrates how different lighting colors affect growth parameters.

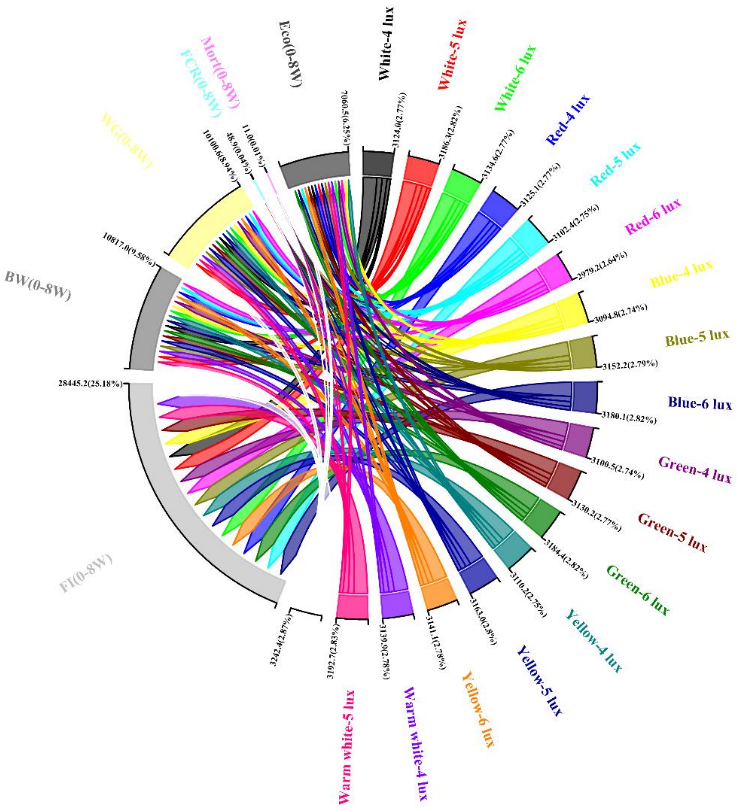

Figure. 5 Chord graph among the growth parameters under different color and intensities (0-8 weeks). Feed Intake (FI), Body weight (BW), Weight gain (WG), Feed conversion ratio (FCR), Mortality (Mort.) Economics of the Experiment (Economic).

4. Discussion

The results of the experiment showed that color of light, intensity of light and interaction of color and intensity of light significantly affect the feed intake of the birds. The observed trends in feed intake across different colors align with the findings of Cherry *et al.* (1962) and Newberry *et al.* (1988), who reported that white light predominantly composed of long wavelengths typically enhances feed intake activities. The increased feed intake under red light conditions is consistent with the literature suggesting that red light enhances activity levels and possibly stimulates hunger or feeding behaviors (Gulizia and Downs, 2021). This response could be attributed to the stimulation of the endocrine system by the red-light wavelength, enhancing the laying hens' feeding actions. Moreover, the interaction between light color and intensity demonstrated significant effects on feed intake. High-intensity treatments, such as 6 lux, were particularly associated with greater feed intake, supporting the notion that higher visibility under stronger light leads to more active consumption (Liu *et al.*, 2018).

The results of the experiment showed that color of light, intensity of light and interaction of color and intensity of light significantly affect the body weight of the birds. The superior performance of warm white light (Specifically designed for birds), particularly at 6 lux, can be attributed to its anti-flicker properties which potentially reduce stress and visual discomfort in chickens, as observed by HATO (2019). Flickering lights are known to stress the nervous system of chickens, negatively impacting growth and welfare (Kavtarashvili and Gladin, 2022; Evans *et al.*, 2012). Meanwhile results are in contradiction to Janczak and Riber (2015), who found that higher body weight was observed in birds under cool white light. A consistent light environment likely promotes higher feed intake and balanced growth. The calming influence of blue light, noted by Olanrewaju *et al.* (2017), appears to lessen stress and enhance metabolic optimization, contributing to the observed weight gains. This suggests that blue light may enhance general well-being without causing overstimulation, unlike higher intensities. Although green light did not lead to the highest growth rates, it still significantly differed from some treatments and may mimic natural conditions that promote tranquility in line with the results of Wei *et al.* (2022). The lesser growth observed under low-intensity red light (4 lux) supports the notion that insufficient intensity fails to stimulate adequate activity and feed intake, critical for optimal growth (Janczak and Riber, 2015; Lewis and Morris, 2000).

The results of the experiment showed that color of light, intensity of light and interaction of color and intensity of light significantly the body weight gain of the birds. The result of this experiment aligns with previous research by Sadrzadeh *et al.* (2013) who found that red LED light did not facilitate an increase in body weight, mirroring the lesser gains noted with red light in this study. Meanwhile, the studies by Jean-Loup *et al.* (2017) supports the observation that lower light intensities might reduce body weights by altering behavioral patterns, such as reducing active time. Furthermore, Mohammed *et al.* (2016) reported that moderate light intensities are optimal to avoid abnormal behaviors, which is corroborated by our findings where higher light intensities under the warm white light notably enhanced physiological responses and weight gain. The study also showed the significant role of light intensity, with 5 lux generally yielding high weight values among all colors, suggesting that an optimal light intensity can enhance visibility for chickens, possibly leading to increased feed intake and subsequent weight gain as observed by Olanrewaju *et al*. (2017). These insights offer valuable implications for optimizing lighting conditions in poultry farming to enhance growth and productivity effectively.

The results of the experiment showed that color of light, intensity of light and interaction of color and intensity of light significantly FCR of the birds. There seems to be a correlation between warm white light and an ability to utilize nutrients more productively or reduce stress for layers. Secondly, the better performance of warm white light in terms of FCR efficiency is consistent with the assumption that its anti-flicker characteristics may reduce stress factors in layers (Kavtarashvili and Gladin, 2022; Evans *et al.,* 2012). The findings of this study are line to the findings of Yang *et al.* (2016) and Riaz *et al.* (2021), who found that white light could improve FCR due to the establishment of circadian rhythms and better welfare. There is enough evidence from previous scientific works to claim that stress can have a significant impact on poultry's metabolic processes reflected in the quality of the feed conversion into body mass (El-Naggar *et al.,* 2019; Wang *et al.,* 2018). Red light, although seemingly related to more activity of birds resulting in sometimes better feed intake, may indeed have the opposite effect in terms of feed conversion (Gulizia and Downs, 2021). The reasons for this are excessive activity or stress under this light, and it does not necessarily mean productive growth. The FCR data also showed the need for optimal light intensity. The higher the intensity and especially under red and warm white lights, the more varied the efficiency of FCR. This suggests that not only color but also the intensity of the light affects how well the birds manage to convert the feed. This, too, supports the findings of El-Sabrout *et al.* (2022), who mentioned that the optimal lighting systems can increase the efficiency of the metabolic process. Current findings validated layer preference for light colors at various light intensities will inform the management of LED colors to meet the pullet demands and it is true that layer color preference in various development stages differs (Li *et al.*, 2019). In addition, different combinations between lighting colors and intensity will highly influence them in future among researchers and breeders as a modern approach to improve productive performances in broilers and layers.

The present study found no difference mortalities, instead found lower mortality rates under warm white light suggest its potential benefits in reducing stress or improving overall environmental conditions conducive to layer health. Numerically higher value of mortality was found under red light, which contrasts with the findings of Svobodova *et al.* (2015), who observed that the lowest mortality rate was 12.65% for the laying hens reared under the red light, whereas the highest mortality was 14.30% for the hens raised under the blue light possibly indicating less stress susceptibility in birds reared under red light. Behavior and stress are other aspects that have been proven to change with light wavelength (Sultana *et al*., 2013). Birds spend more time sitting or standing in short wavelengths and in longer wavelengths show locomotion. Birds raised in red/yellow light demonstrate tonic immobility longer, indicating more fear than green and white light exposed, which may reduce time for bird to feed (Huber-Eicher *et al.,* 2013). This may be the reason in this experiment for higher mortality in red light. It can be observed from the results on light intensity that higher intensities are generally associated with a slight increase in mortality. This pattern could imply that while certain intensities ensure appropriate visibility and activity, they could cause physiological stress on the birds when they are not optimized or congruent with the birds' requirements, raising the possibility of increasing mortality (Kang *et al.*, 2023; Raccoursier *et al.,* 2019). The combined effects of light color and intensity produce mixed results, with some combinations such as red at 5 lux and 6 lux, which were associated with increased mortality. These variations reveal the vital role of ensuring a well-balanced lighting system in the poultry setting for optimal health outcomes and reduced mortality (Chew *et al.*, 2021).

In the present study on the economics of rearing layers were also observed under different light color and light intensity (Table 8). The results of the experiment showed that color of light, intensity of light and interaction of color and intensity of light did not significantly affect the cost of production of the birds at 8th weeks of age. However apparently lowest cost of production was observed in the birds kept under blue light having 4 lux light intensity and highest cost of production was observed in the birds kept under warm white light having 6 lux intensity. These results are in contradiction with findings from Soliman and El-Sabrout (2022), who noted increased activity in birds under red light conditions with higher intensities, potentially leading to increased feed consumption. The results present study is not in line with the finding of El-Sabrout *et al.* (2022) who observed that light intensity and color can significantly influence economic outcomes. The contradiction in the result may be due to the calculation of the economics of birds at the end of production cycle.

5. Conclusion

It can be concluded that the warm white color having 6 lux showed significantly better weight gain, feed consumption and feed conversion ratio. Moreover, keeping in view the economical consideration, it can be concluded that during brooding phase any of light treatment conducted in these experiments may be applied but the warm white light with 6 lux and blue light under 4 lux light intensity can be used during brooding phase in layers for comparatively better output.

6. Data availability

Data will be provided on the demand of editor.

7. Declaration of Funding

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9. Conflict of interest

The authors declare that they have no conflict of interest.

10. Author contributions

Dr. Fawwad Ahmad and Dr. Muhammad Yousaf designed the research plan, Dr. Rao Zahid Abbas contributed in final review and critical analysis. Ahmad Hamad Sheir conducted field research and sample analysis in the laboratory. All authors wrote, edited, read, and approved the final manuscript.

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