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EFFECT OF VARIOUS LED LIGHT COLORS AND INTENSITY LEVELS ON GROWTH PERFORMANCE AND COST-EFFECTIVENESS IN LAYERS KEPT IN ENVIRONMENT CONTROL HOUSE DURING GROWING PHASE

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Abstract

In the current study, the effects of various LED light colors and intensities on the production performance of 720 Babcock® White layers were determined. The layer birds were reared for 8 weeks from the age of 9 weeks to 16 weeks and divided into 18 treatment groups, each with four replicates of 10 birds, in a 6x3 factorial randomized design. The birds were housed in environmental control housing containing 3-tiered laying cages (2 ft x 4 ft x 2 ft) with sloping wire. Light treatments of 6 different colors, cool white (control group), red, blue, green, yellow, and warm white light (Specifically designed for birds/ Sterna light) light with 3 different levels of light intensities (8 lux, 10 lux, and 12 lux), were provided in the rearing phase (9-16 weeks). The wavelengths of different colors of light were cool white 590 nm (400-800 nm), red 630 nm (625-660 nm), blue 470 nm (430-505 nm), green 535 nm (500-565 nm), yellow 585 nm (575-590 nm), and warm white 580 nm (350-830 nm). Weekly evaluations for feed intake, body weight, body weight gain, feed conversion ratio (FCR) was determined. Weekly evaluations for weekly weight, feed intake, body weight, body weight gain, feed conversion ratio (FCR), mortality and economic were determined. The observed data was analyzed with Minitab 18 using factorial arrangements to determine means, p-value and errors. The graphical presentation was done by Origin Pro 2024 and RStudio. The results demonstrated that there was significant ($p<0.05$) effect of different light colors and intensities on weekly weight, feed intake, body weight, body weight gain and feed conversion ratio (FCR). Interaction among light color and intensities was also observed to be significant ($p<0.05$). Layers exposed to warm white light showed the highest weights consistently across the weeks, starting from 737.75 g in the 9th week to 1351.3 g by the 16th week. Red light caused the highest feed intake when, starting from around 341-345 g in the first week and increasing to about 493-494 g by the eighth week. Layers exposed to warm white light had the highest weight gain throughout the weeks, starting from 94.16 g in the 9th week to 82.08 g in the 16th week. Red light had the highest total mortality rate, with a noticeable increase during the last four weeks. The birds under red light having 12 lux intensity had the significantly lowest production cost (Rs: 1053.9). During growing stage (9-16 weeks) red light having 12 lux intensity may be applied to reduce the cost of production.

Keywords: Layer Birds; Light Colors; Intensities; Growth Performance; Feed Conversion Ratio (FCR); Economics.

INTRODUCTION

Light spectrum is the combination of different wavelengths of electromagnetic radiation produced by a lighting source (Archer *et al.,* 2018). There is increasing attention in the literature with respect to LED spectrum reflecting the lighting quality as part of lighting programs (Vasdal *et al.,* 2022). It is shown that the different monochromatic light or different color temperature exert variable effects for the production efficiency (Wei *et al.,* 2020; Archer*,* 2018; Yang *et al.*, 2016). The monochromatic lights of short-wavelength (blue and green) reduce stress and promote growth, while the long-wavelength red monochromatic light promotes reproduction (Huber-Eicher *et al.,* 2013). In poultry farming, artificial lighting has been used to affect physiological reactions and metabolism while boosting productivity. The three main components of artificial lighting are light wavelength (color), light intensity (brightness), and lighting time (photoperiod) (Wei *et al.,* 2020; Soliman and El-Sabrout, 2020).

Two important aspects impacting poultry production and behavior are the quantity (intensity) and quality (color) of light (Parvin *et al*., 2014; Elkomy *et al*., 2019; Soliman and El-Sabrout, 2020). Light intensity (also called illuminance or density), as one of the primary components of light that affects lighting quantity, can also influence birds' behavior and productivity (Patel *et al.,* 2016). Light is a crucial environmental factor that affects bird behavior, development, production performance, health, and well-being (Parvin *et al.,* 2014; Soliman and El-Sabrout 2020). Light plays a central role in modulating animal behavior and is a critical environmental factor that can affect the physiological processes, performance, and welfare of many animals and birds (Fernandes *et al.,* 2013; Aulsebrook *et al.,* 2021).

Previous research has demonstrated that the color of the light has a significant impact on the physiology, behavioral, and growth efficiency of chicken (Nega, 2024; Lewis and Morris, 2000). Within the visible spectrum, the effects of the long-wavelength red light on poultry activity, sexual development, and maturity have been shown to be beneficial (Sultana *et al*., 2013; Lewis and Morris, 2000). On the other hand, the shorter-wavelength blue and green lights have been shown to improve growth and immune system function, as well as calm birds (Sultana *et al*., 2013; Cao *et al*., 2008).

Research has investigated the preferences of poultry for several light colors, including white, red, blue, and green. Li *et al*. (2019) conducted a study on layer pullet preference for different light hues. They discovered that the pullets showed a preference for staying under blue light and eating under white light. Senaratna *et al*. (2012) conducted a preference test for layer pullets using four different light colors. They found that the layers showed a preference for the red light once the lights were turned on. In a study conducted by Rierson (2011), layer pullets were given the option of either pelleted or crumbled feed and were exposed to four different light colors. The results showed that the layers showed

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the highest preference for white light, followed by red light. Effective light management is crucial for layer pullets since it directly impacts their production performance during the laying stage (Hy-Line International, 2013). Evaluating the feeding and drinking habits of layer pullets under various selectable light colors is crucial for gaining insights into their actual light requirements. This information can then be used to effectively manage the light color and allocate resources for pullets (Wei *et al*., 2020; Borille *et al*., 2015). There is a high probability that the white LED and monochrome LED lights that are widely used in poultry production (Liu *et al*., 2017; Hassan *et al*., 2014, 2013) do not fulfill the requirements for the welfare and health of layer chickens.

This is especially true during the brooding and rearing periods (0-20 weeks of age), which are times when phased spectral control may be necessary to accommodate the growth of the immune and digestive system, as well as the skeletal and sexual development of the chickens as they get more mature (Sun *et al*., 2023; Ashabranner, 2023). Our hypothesis was that providing layer chickens with LED lights of varying colors and intensities throughout the rearing phase (9-16 weeks) would enhance their growth performance. Nevertheless, there is a scarcity of data about the impact of phased spectrum management on the performance of layer chickens, particularly during the raising stages. Enhanced comprehension of these impacts could incentivize the sector to employ light more extensively to enhance production efficiency.

MATERIALS AND METHODS

The current study was performed to determine the effect of different LED light colors and intensities on the growth 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 growing phase (9-17 weeks).

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. Variations in daily temperature (^oF) and humidity (%) were noted using a wet and dry bulb hygrometer. The temperature and humidity were maintained according to rearing guidelines of the Babcock® white strain throughout the rearing period. The chicks were fed a grower diet (2,700 kcal/kg ME and 18% protein) from 9 to 14 weeks (2,700 kcal/kg ME and 18% protein) between 14 and 18 weeks of age.

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Lighting Scheme

Light intensities of 8 lux, 10 lux, and 12 lux were provided with six different light colors. Hence, treatments provided were Cool white-LED + 8 lux (control group), Cool white-LED + 10 lux (control group), Cool white-LED + 12 lux (control group), Red-LED + 8 lux, Red-LED + 10 lux, Red-LED + 12 lux, Blue-LED + 8 lux, Blue-LED + 10 lux, Blue-LED + 12 lux, Green-LED + 8 lux, Green-LED + 10 lux, Green-LED + 12 lux, Yellow-LED + 8 lux, Yellow-LED + 10 lux, Yellow-LED + 12 lux, Warm white light + 8 lux, Warm white light + 10 lux, and Warm white light + 12 lux as mentioned in Table 4.1. The wavelengths of different colors of light were: Cool white 590 nm (400-800 nm), red 630 nm (625-660 nm), blue 470 nm (430-505 nm), green 535 nm (500-565 nm), yellow 585 nm (575-590 nm), and warm white light 580 nm (350-830 nm) as depicted in Figure 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6. Each treatment was further divided into 4 replications, and each replicate had 10 birds, hence 40 birds in each treatment. The intensity of light was measured using a digital light meter (lux meter) positioned at the head height of birds without the interference of external light.

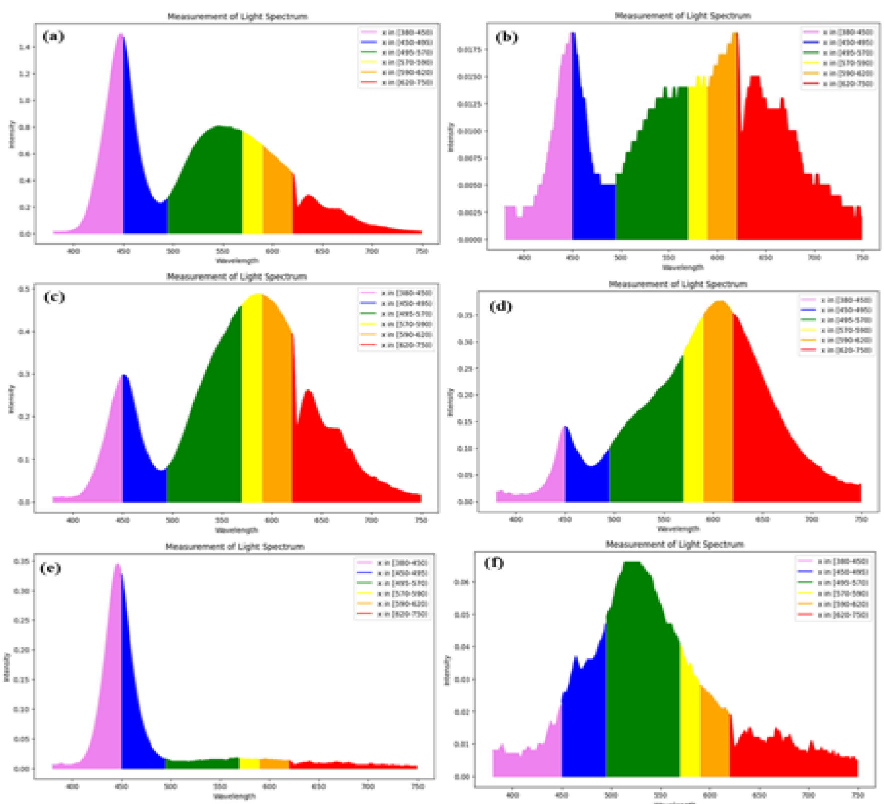

Figure 1: (a) Light spectrum of cool white Color light (b) Light spectrum of red color light (c) Light spectrum of warm white color light (d) Light spectrum of yellow color light (e) Light spectrum of blue color light (f) Light spectrum of green color light

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Table 1: Experimental design of LED light treatments

Treatment	Color of Lights	Light Intensity (Lux) Experiment- II (9-16 weeks)
1	Cool white (Control)	8
2	Cool white (Control)	10
3	Cool white (Control)	12
4	Red	8
5	Red	10
6	Red	12
7	Blue	8
8	Blue	10
9	Blue	12
10	Green	8
11	Green	10
12	Green	12
13	Yellow	8
14	Yellow	10
15	Yellow	12
16	Warm white	8
17	Warm white	10
18	Warm white	12

Electric dimmer designed to control the intensity of light

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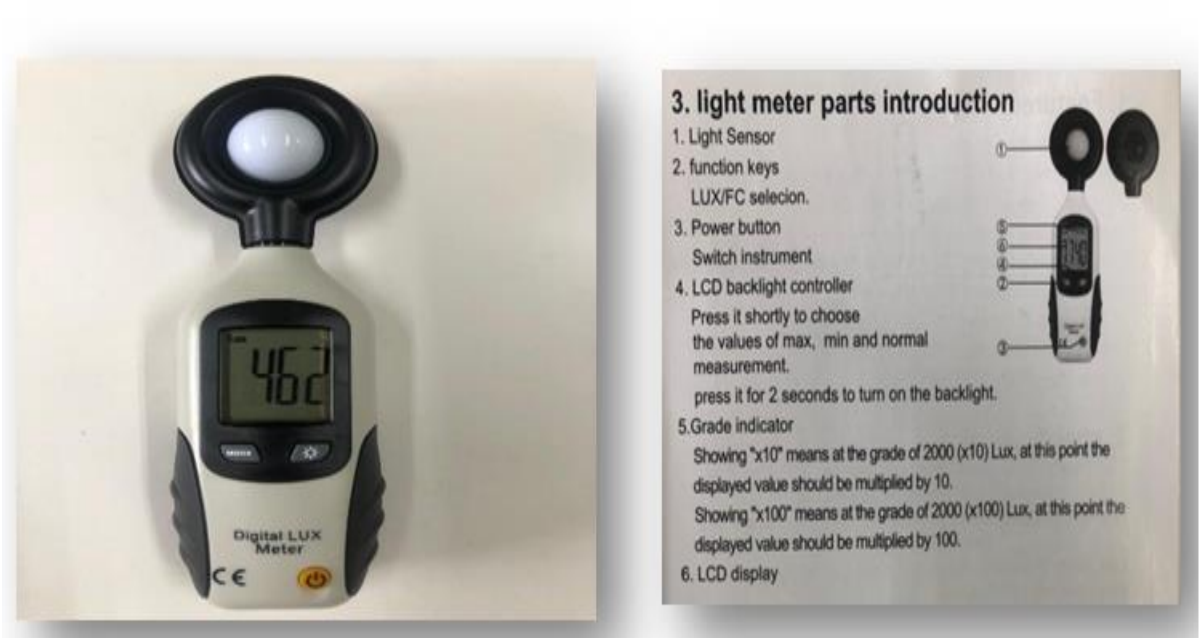

Lux Meter (Measure the intensity of light)

Table 2: Vaccination Schedule

Age (day)	Vaccine	Route
77	Newcastle + Infectious Bronchitis	Drinking water
98	Coryza	Subcutaneous
112	Newcastle + Infectious Bronchitis + Egg Drop Syndrome	Subcutaneous
After every two months	Newcastle disease (Lasota)	Drinking water

Parameter's Evaluation

The effect of different light treatments was determined on body weight gain from 9 to 16 weeks of age.

Moreover, production parameters regarding feed intake, body weight, body weight gain, mortality percentage, and FCR were evaluated weekly.

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)

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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 the birds from each replicate were weighed together, and the mean body weight was calculated.

(Nguyen, 2021)

Feed conversion ratio (FCR)

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

FCR = Feed intake (g) / Weight gain (g)

(Mangnale, 2019)

Mortality

Throughout the experiment, mortality was also calculated.

Economics

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

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.

RESULTS

Feed Intake (9-16 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 per week and over eight weeks of the birds.

According to the summarized data from (Tables. 3) the interaction between the variables and their effect on weekly feed intake can be observed. There was a notable difference in the quantity of feed consumed by the layers based on color and intensity of the light.

Red light caused the highest feed intake when, starting from around 341-345 g in the first week and increasing to about 493-494 g by the eighth week.

The interaction between light colors and intensities also demonstrated significant variations, with specific combinations like red at 12 lux leading to the highest overall intake (491 g in the 16th week). The warm white light showed a more moderate intake, with the lowest feed intake observed starting at 334 g and reaching 480 g by the eighth week.

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Table 3: Effect of light color and intensity on weekly feed intake (g) of layers (9-16 weeks)

Treatments	Feed intake (g)							
	9th week	10th week	11th week	12th week	13th week	14th week	15th week	16th week
Main effect (light colors)								
Cool white	341.08^{b}	363.42^{b}	385.25^{a}	408.25^{a}	432.08^{a}	452.92^{a}	471.83^{a}	493.08^{a}
Red	345.25^{a}	368.67^{a}	388.50^{a}	411.50^{a}	430.42^{a}	452.33^{a}	471.42^{a}	494.08^{a}
Blue	338.58^{bc}	360.42^{c}	380.17^{b}	403.17^{b}	423.75^{b}	444.83^{b}	464.25^{b}	486.67^{b}
Green	334.50^{d}	356.92^{d}	380.67^{b}	403.67^{b}	422.42^{b}	443.00^{b}	463.83^{b}	485.83^{b}
Yellow	335.83^{cd}	358.58^{cd}	381.00^{b}	403.58^{b}	423.50^{b}	444.50^{b}	465.00^{b}	487.58^{b}
Warm white	333.75^{d}	352.25^{e}	378.83^{b}	401.83^{b}	418.92^{c}	436.83^{c}	460.00^{c}	480.83^{c}
SEM	±0.84	±0.55	±0.82	±0.85	±0.80	±0.67	±0.87	±0.82
Main effect (light intensity)								
8 lux	334.50^{c}	356.83^{c}	379.54^{b}	402.54^{b}	421.71^{c}	449.38^{a}	462.00^{c}	483.96^{c}
10 lux	338.92^{b}	360.96^{b}	383.04^{a}	405.83^{a}	425.63^{b}	446.38^{b}	466.96^{b}	488.25^{b}
12 lux	341.08^{a}	362.33^{a}	384.62^{a}	407.62^{a}	428.21^{a}	449.38^{a}	469.21^{a}	491.83^{a}
SEM	±0.59	±0.39	±0.58	±0.6	±0.57	±0.47	±0.62	±0.58
Interaction (light colors intensity)*								
Cool white-8 lux	333.25^{de}	351.75^{h}	376.75^{ef}	399.75^{de}	423.00^{de}	441.50^{fg}	460.25^{f}	482.00^{fg}
Cool white-10 lux	335.75^{cde}	363.00^{cd}	382.50^{cdef}	405.50^{bcde}	431.00^{bc}	451.00^{cd}	471.50^{bcd}	490.75^{cde}
Cool white-12 lux	354.25^{a}	375.50^{a}	396.50^{a}	419.50^{a}	442.25^{a}	466.25^{a}	483.75^{a}	506.50^{a}
Red-8 lux	342.75^{bc}	369.75^{b}	390.00^{ab}	413.00^{ab}	431.75^{bc}	456.00^{bc}	473.00^{bc}	494.50^{bc}
Red-10 lux	354.00^{a}	375.75^{a}	395.25^{a}	418.25^{a}	437.50^{ab}	458.50^{b}	479.00^{ab}	501.25^{ab}
Red-12 lux	339.00^{bcd}	360.50^{de}	380.25^{cdef}	403.25^{cde}	422.00^{de}	442.50^{fg}	462.25^{ef}	486.50^{def}
Blue-8 lux	333.25^{de}	355.50^{fgh}	375.75^{f}	398.75^{e}	418.00^{e}	439.00^{fgh}	459.00^{f}	483.00^{fg}
Blue-10 lux	336.75^{cde}	358.75^{def}	377.75^{def}	400.75^{de}	419.75^{e}	440.50^{fg}	461.50^{ef}	480.75^{fg}
Blue-12 lux	345.75^{b}	367.00^{bc}	387.00^{bc}	410.00^{bc}	433.50^{bc}	455.00^{bc}	472.25^{bc}	496.25^{bc}
Green-8 lux	333.25^{de}	353.50^{gh}	377.75^{def}	400.75^{de}	416.25^{e}	436.50^{gh}	456.25^{f}	476.00^{g}
Green-10 lux	334.75^{de}	356.25^{efgh}	380.00^{cdef}	403.00^{cde}	420.75^{de}	441.25^{fg}	461.75^{ef}	484.50^{ef}
Green-12 lux	335.50^{cde}	361.00^{de}	384.25^{bcd}	407.25^{bcd}	430.25^{c}	451.25^{cd}	473.50^{bc}	497.00^{bc}
Yellow-8 lux	334.00^{de}	357.75^{efg}	381.00^{cdef}	404.00^{cde}	421.75^{de}	442.75^{ef}	464.00^{def}	486.25^{def}
Yellow-10 lux	337.50^{cde}	359.50^{def}	383.50^{bcde}	405.25^{cde}	427.75^{cd}	448.75^{de}	468.75^{cde}	492.50^{cd}
Yellow-12 lux	336.00^{cde}	358.50^{def}	378.50^{def}	401.50^{de}	421.00^{de}	442.00^{fg}	462.25^{ef}	484.00^{ef}

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Warm white-8 lux	330.50^{e}	352.75^{h}	376.00^{f}	399.00^{e}	419.50^{e}	433.00^{h}	459.50^{f}	482.00^{fg}
Warm white-10 lux	334.75^{de}	352.50^{h}	379.25^{def}	402.25^{de}	417.00^{e}	438.25^{fgh}	459.25^{f}	479.75^{fg}
Warm white-12 lux	336.00^{cde}	351.50^{h}	381.25^{cdef}	404.25^{cde}	420.25^{e}	439.25^{fg}	461.25^{ef}	480.75^{fg}
SEM	±1.46	±0.96	±1.42	±1.48	±1.39	±1.16	±1.52	±1.42
Level of significance								
Light colors	0	0	0	0	0	0	0	0
Light intensity	0	0	0	0	0	0	0	0
Interaction	0	0	0	0	0	0	0	0
a,b,c,d Values within a column with different superscript are significantly different (P<0.05). Data are presented as mean±SEM.								

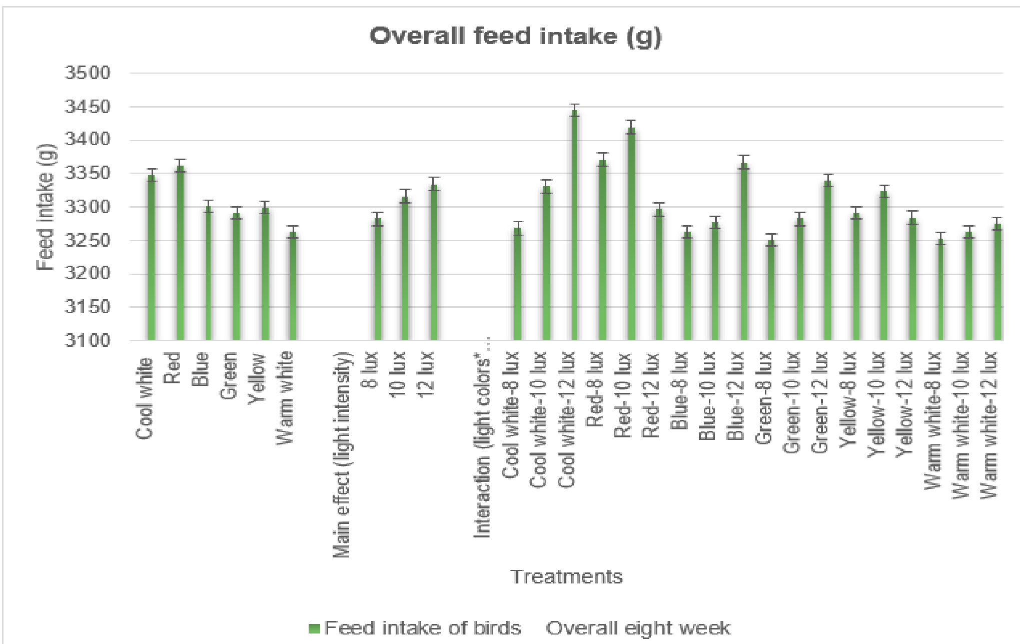

Figure 2: Effect of light color and intensity on weekly overall feed intake of layers (9-16 weeks)

Body Weight (9-16 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 of the birds. The effects of the different colors and intensities of light on the layers' body weight throughout the eight weeks are shown in (Table. 4) and Figure 3. Shows that during the eight weeks, the warm white light with 12 lux light intensity demonstrated highly significant ($p<0.05$) results with highest mean values of weekly weight. For all the weeks, for instance, warm white light led to the highest body weights with the average significantly different from the other light colors such as white, red, blue, green, and yellow. Layers exposed to warm

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white light showed the highest weights consistently across the weeks, starting from 737.75 g in the 9th week to 1351.3 g by the 16th week. In contrast, layers under red light exhibited the lowest weights, beginning at 642.00 g in the 9th week and reaching 1179.6 g by the 16th week, suggesting that red light may be less conducive to weight gain. The effects of light intensity also showed significant ($p<0.05$) differences, with 10 lux generally leading to higher weights compared to 8 lux and 12 lux. The blue light of 12 lux also portrays significant ($p<0.05$) results. Although green light did not considerably outshine the performance of warm white and blue light, its difference was significantly ($P<0.05$) different with mean value of 687.67 g as depicted in (Figure 3).

Table 4: Effect of light color and intensity on weekly weight (g) of layers (9-16 weeks)

Treatments	Weekly weight (g)							
	9th week	10th week	11th week	12th week	13th week	14th week	15th week	16th week
Main effect (light colors)								
Cool white	692.75^{b}	780.25^{b}	866.83^{b}	953.7^{b}	1039.3^{b}	1122.6^{b}	1202.6^{b}	1277.2^{c}
Red	642.00^{d}	727.42^{d}	811.58^{e}	894.8^{d}	971.9^{e}	1044.4^{e}	1112.6^{e}	1179.6^{f}
Blue	687.33^{c}	774.17^{c}	859.25^{d}	944.3^{c}	1027.7^{c}	1110.9^{c}	1191.3^{c}	1268.5^{d}
Green	687.67^{c}	775.58^{c}	862.92^{c}	951.5^{b}	1038.4^{b}	1124.5^{b}	1205.9^{b}	1283.5^{b}
Yellow	688.58^{c}	775.08^{c}	859.00^{d}	940.6^{c}	1019.0^{d}	1097.9^{d}	1171.8^{d}	1242.9^{e}
Warm white	737.75^{a}	831.08^{a}	920.08^{a}	1010.3^{a}	1096.7^{a}	1183.2^{a}	1269.3^{a}	1351.3^{a}
SEM	±0.65	±0.70	±0.81	±0.91	±0.91	±0.92	±0.94	±0.92
Main effect (light intensity)								
8 lux	683.67^{c}	770.88^{c}	856.37^{c}	941.46^{c}	1024.8^{c}	1122.8^{a}	1184.8^{c}	1259.3^{c}
10 lux	697.96^{a}	785.92^{a}	872.00^{a}	958.13^{a}	1041.0^{a}	1106.5^{c}	1201.4^{a}	1276.3^{a}
12 lux	686.42^{b}	775.00^{b}	861.46^{b}	948.04^{b}	1030.8^{b}	1112.5^{b}	1190.6^{b}	1265.9^{b}
SEM	±0.46	±0.49	±0.57	±0.64	±0.64	±0.65	±0.66	±0.65
Interaction (light colors intensity)*								
Cool white-8 lux	685.00^{i}	767.75^{ij}	850.75^{gh}	931.5^{hi}	1013.8^{ij}	1093.5^{h}	1168.3^{j}	1238.8^{i}
Cool white-10 lux	706.75^{cd}	794.00^{d}	879.75^{cd}	967.3^{cd}	1052.5^{c}	1135.3^{de}	1216.0^{ef}	1290.8^{e}
Cool white-12 lux	686.50^{hi}	779.00^{fg}	870.00^{e}	962.3^{def}	1051.8^{cd}	1139.0^{cd}	1223.5^{de}	1302.0^{d}
Red-8 lux	666.00^{k}	754.50^{l}	841.75^{i}	927.0^{ij}	1006.5^{j}	1082.0^{i}	1154.3^{k}	1224.5^{j}
Red-10 lux	648.00^{l}	734.50^{m}	820.00^{j}	904.5^{k}	982.5^{l}	1056.0^{k}	1124.8^{m}	1192.0^{l}
Red-12 lux	612.00^{m}	693.25^{n}	773.00^{k}	853.0^{l}	926.8^{m}	995.3^{l}	1058.8^{n}	1122.3^{m}
Blue-8 lux	678.00^{j}	765.50^{ijk}	851.25^{gh}	938.8^{gh}	1024.5^{h}	1111.3^{g}	1195.3^{gh}	1275.0^{f}
Blue-10 lux	699.00^{ef}	785.50^{e}	870.50^{e}	954.8^{f}	1037.8^{ef}	1120.3^{f}	1199.5^{g}	1275.3^{f}
Blue-12 lux	685.00^{i}	771.50^{hi}	856.00^{fg}	939.5^{gh}	1020.8^{hi}	1101.3^{h}	1179.3^{i}	1255.3^{h}
Green-8 lux	676.75^{j}	761.50^{jk}	846.50^{hi}	932.5^{hi}	1016.0^{i}	1097.5^{h}	1172.8^{ij}	1245.3^{i}
Green-10 lux	694.50^{fg}	782.25^{ef}	869.25^{e}	957.5^{ef}	1044.0^{de}	1129.8^{e}	1211.5^{f}	1289.3^{e}

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Green-12 lux	691.75^{gh}	783.00^{ef}	873.00^{de}	964.5^{de}	1055.3^{c}	1146.3^{c}	1233.5^{c}	1316.0^{c}
Yellow-8 lux	687.00^{hi}	775.50^{gh}	861.50^{f}	945.0^{g}	1028.8^{gh}	1111.5^{g}	1190.8^{h}	1265.0^{g}
Yellow-10 lux	702.00^{de}	788.50^{de}	872.75^{de}	954.5^{f}	1033.0^{fg}	1112.8^{fg}	1187.8^{h}	1260.0^{gh}
Yellow-12 lux	676.75^{j}	761.25^{k}	842.75^{i}	922.3^{j}	995.3^{k}	1069.5^{j}	1137.0^{l}	1203.8^{k}
Warm white-8 lux	709.25^{c}	800.50^{c}	886.50^{c}	974.0^{c}	1059.0^{c}	1143.3^{cd}	1227.3^{cd}	1307.0^{d}
Warm white-10 lux	737.50^{b}	830.75^{b}	919.75^{b}	1010.3^{b}	1096.0^{b}	1182.8^{b}	1269.0^{b}	1350.8^{b}
Warm white-12 lux	766.50^{a}	862.00^{a}	954.00^{a}	1046.8^{a}	1135.0^{a}	1223.5^{a}	1311.5^{a}	1396.3^{a}
SEM	±1.12	±1.21	±1.40	±1.57	±1.58	±1.60	±1.63	±1.59
Level of significance								
Light colors	0	0	0	0	0	0	0	0
Light intensity	0	0	0	0	0	0	0	0
Interaction	0	0	0	0	0	0	0	0
[a,b,c,d] Values within a column with different superscript are significantly different ($P<0.05$). Data are presented as mean±SEM.								

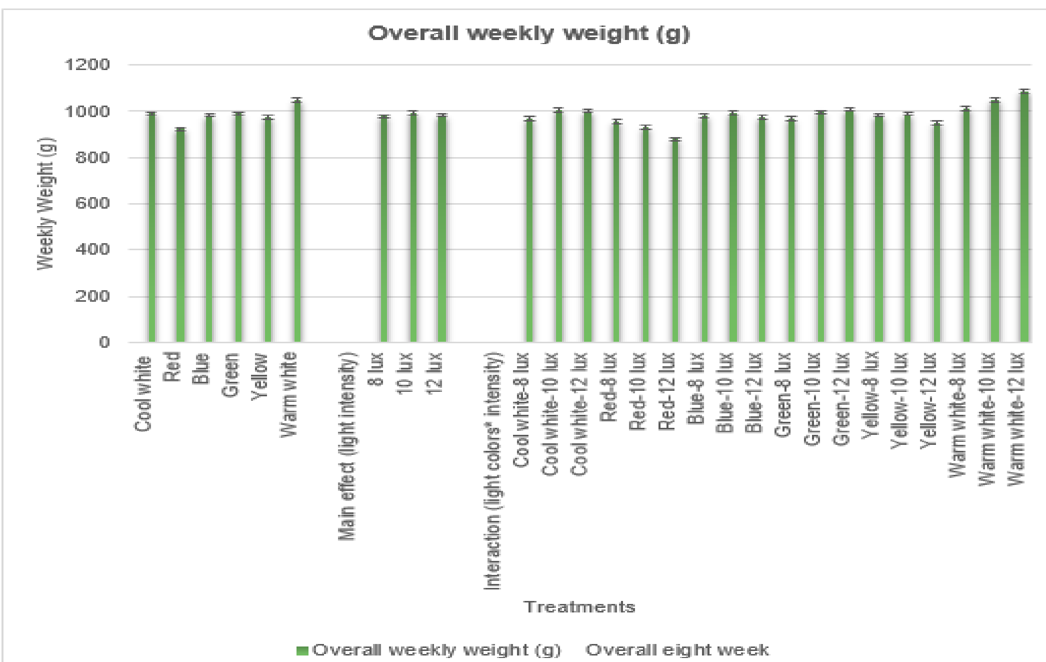

Figure 3: Effect of light color and intensity on weekly overall weight of layers (9-16 weeks)

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Weekly Weight Gain (9-16 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. Shows that light color significantly ($p<0.05$) influenced weight gain in (Table. 5).

Layers exposed to warm white light had the highest weight gain throughout the weeks, starting from 94.16 g in the 9th week to 82.08 g in the 16th week. Conversely, layers under red light showed the lowest weight gain, ranging from 85 g in the first week to 67 g in the eighth week.

Red light with all three light intensities 8, 10 and 12 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 as shown in Table 5 and Figure 4.

Table 5: Effect of light color and intensity on weekly weight gain (g) of layers (9-16 weeks)

Treatments	Weight gain (g)							
	9th week	10th week	11th week	12th week	13th week	14th week	15th week	16th week
Main effect (light colors)								
Cool white	88.58^{c}	87.50^{bc}	86.58^{b}	86.83^{c}	85.66^{b}	83.25^{b}	80.00^{c}	74.58^{c}
Red	85.00^{e}	85.41^{e}	84.16^{d}	83.25^{e}	77.08^{e}	72.50^{d}	68.16^{e}	67.00^{e}
Blue	85.50^{e}	86.83^{cd}	85.08^{c}	85.08^{d}	83.33^{c}	83.25^{b}	80.41^{c}	77.16^{b}
Green	87.50^{d}	87.91^{b}	87.33^{b}	88.58^{b}	86.91^{a}	86.08^{a}	81.41^{b}	77.58^{b}
Yellow	89.66^{b}	86.50^{d}	83.91^{d}	81.58^{f}	78.41^{d}	78.91^{c}	73.91^{d}	71.08^{d}
Warm white	94.16^{a}	93.33^{a}	89.00^{a}	90.25^{a}	86.33^{ab}	86.50^{a}	86.08^{a}	82.08^{a}
SEM	±0.25	±0.17	±0.21	±0.19	±0.22	±0.16	±0.18	±0.16
Main effect (light intensity)								
8 lux	87.62^{c}	87.20^{c}	85.50^{b}	85.08^{b}	83.29^{a}	81.75	78.25^{ab}	74.50^{c}
10 lux	88.29^{b}	87.95^{b}	86.08^{a}	86.12^{a}	82.83^{ab}	81.83	78.62^{a}	74.91^{b}
12 lux	89.29^{a}	88.58^{a}	86.45^{a}	86.58^{a}	82.75^{b}	81.66	78.12^{b}	75.33^{a}
SEM	±0.17	±0.12	±0.14	±0.13	±0.13	±0.11	±0.13	±0.11
Interaction (light colors intensity)*								
Cool white-8 lux	84.50^{h}	82.75^{g}	83.00^{gh}	80.75^{hi}	82.25^{fg}	79.75^{h}	74.75^{g}	70.50^{h}
Cool white-10 lux	87.00^{g}	87.25^{de}	85.75^{ef}	87.50^{cd}	85.25^{de}	82.75^{ef}	80.75^{de}	74.75^{ef}
Cool white-12 lux	94.25^{bc}	92.50^{bc}	91.00^{ab}	92.25^{a}	89.50^{ab}	87.25^{bc}	84.50^{c}	78.50^{cd}
Red-8 lux	86.25^{gh}	88.50^{d}	87.25^{de}	85.25^{ef}	79.50^{hi}	75.50^{i}	72.25^{h}	70.25^{h}
Red-10 lux	86.75^{gh}	86.50^{e}	85.50^{ef}	84.50^{efg}	78.00^{i}	73.50^{j}	68.75^{i}	67.25^{i}
Red-12 lux	82.00^{i}	81.25^{g}	79.75^{i}	80.00^{i}	73.75^{j}	68.50^{k}	63.50^{j}	63.50^{j}
Blue-8 lux	86.25^{gh}	87.50^{de}	85.75^{ef}	87.50^{cd}	85.75^{d}	86.75^{c}	84.00^{c}	79.75^{c}
Blue-10 lux	85.00^{gh}	86.50^{e}	85.00^{f}	84.25^{fg}	83.00^{fg}	82.50^{f}	79.25^{ef}	75.75^{e}
Blue-12 lux	85.25^{gh}	86.50^{e}	84.50^{fg}	83.50^{g}	81.25^{gh}	80.50^{gh}	78.00^{f}	76.00^{e}
Green-8 lux	86.25^{gh}	84.75^{f}	85.00^{f}	86.00^{de}	83.50^{ef}	81.50^{fg}	75.25^{g}	72.50^{g}
Green-10 lux	86.75^{gh}	87.75^{de}	87.00^{e}	88.25^{c}	86.50^{cd}	85.75^{cd}	81.75^{d}	77.75^{d}
Green-12 lux	89.50^{ef}	91.25^{c}	90.00^{bc}	91.50^{ab}	90.75^{a}	91.00^{a}	87.25^{ab}	82.50^{b}
Yellow-8 lux	92.00^{cd}	88.50^{d}	86.00e^{f}	83.50^{g}	83.75^{ef}	82.75^{ef}	79.25^{ef}	74.25^{f}
Yellow-10 lux	89.75^{de}	86.50^{e}	84.25^{fg}	81.75^{h}	78.50^{i}	79.75^{h}	75.00^{g}	72.25^{g}

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Yellow-12 lux	87.25^{fg}	84.50^{f}	81.50^{hi}	79.50^{i}	73.00^{j}	74.25^{ij}	67.50^{i}	66.75^{i}
Warm white-8 lux	90.50^{de}	91.25^{c}	86.00^{ef}	87.50^{cd}	85.00^{de}	84.25^{de}	84.00^{c}	79.75^{b}
Warm white-10 lux	94.50^{b}	93.25^{b}	89.00^{cd}	90.50^{b}	85.75^{d}	86.75^{0c}	86.25^{b}	81.75^{b}
Warm white-12 lux	97.50^{a}	95.50^{a}	92.00^{a}	92.75^{a}	88.25^{bc}	88.50^{b}	88.00^{a}	84.75^{a}
SEM	±0.43	±0.30	±0.36	±0.33	±0.38	±0.29	±0.32	±0.28
Level of significance								
Light colors	0	0	0	0	0	0	0	0
Light intensity	0	0	0	0	0.04	0.62	0.03	0
Interaction	0	0	0	0	0	0	0	0
^{a,b,c,d} Values within a column with different superscript are significantly different (P<0.05). Data are presented as mean±SEM.								

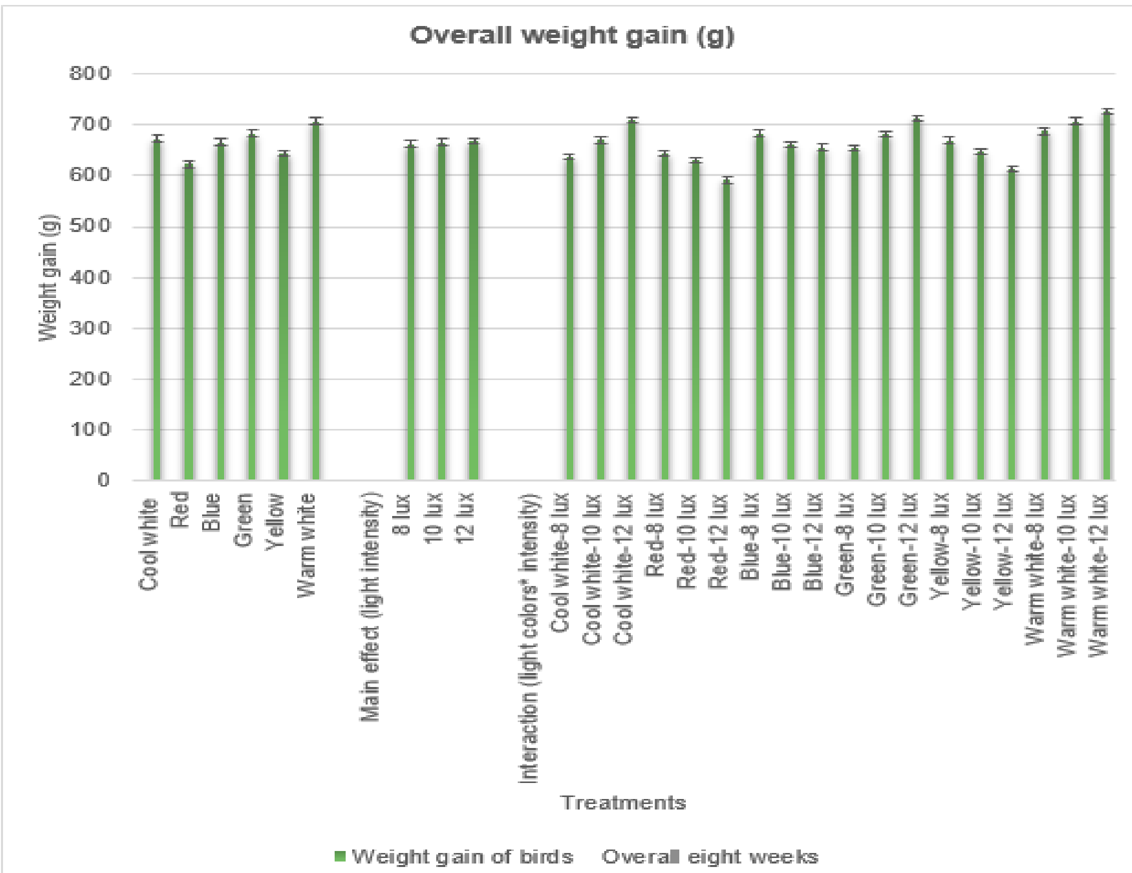

Figure 4: Effect of light color and intensity on weekly overall weight gain of layers (9-16 weeks)

Feed Conversion Ratio (FCR)

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 FCR of the birds. (Table.6 and Figure 5). 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

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different light colors differ significantly. Warm white color with 8 lux light intensity demonstrated the efficient FCR values overall, which became most notable in the later weeks, with several values approaching as little as 3.54 in the 16th week. Moreover, red was the least efficient light in maintaining FCR, with the highest weekly value of 7.38 in the final week. The interaction between light color and intensity highlighted that warm white light at 12 lux achieved the best FCR (3.90 in the first week to 5.67 in the eighth week). Conversely, red light at 12 lux had the worst FCR (4.59 in the 9th week to 7.66 in the 16th week).

Table 6: Effect of light color and intensity on weekly feed conversion ratio of layers (9-16 weeks)

Treatments	FCR							
	9th week	10th week	11th week	12th week	13th week	14th week	15th week	16th week
Main effect (light colors)								
Cool white	3.85c	4.15b	4.45c	4.71b	5.04d	5.44c	5.90c	6.61c
Red	4.06a	4.31a	4.62a	4.94b	5.58a	6.24a	6.93a	7.38a
Blue	3.96b	4.15b	4.46c	4.74b	5.08c	5.35d	5.78d	6.31d
Green	3.82c	4.06c	4.36d	4.56c	4.86e	5.15e	5.71e	6.27e
Yellow	3.74d	4.14b	4.54b	4.94a	5.41b	5.64b	6.31b	6.87b
Warm white	3.54e	3.77d	4.26	4.45d	4.85e	5.05f	5.34f	5.86f
SEM	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01	±0.01
Main effect (light intensity)								
8 lux	3.82b	4.09	4.44b	4.73	5.06c	5.41c	5.92c	6.59a
10 lux	3.84a	4.1	4.45ab	4.71	5.15b	5.47b	5.97b	6.54b
12 lux	3.83ab	4.1	4.46a	4.72	5.21a	5.55a	6.09a	6.51c
SEM	±0.005	±0.004	±0.005	±0.006	±0.005	±0.006	±0.005	±0.005
Interaction (light colors intensity)*								
Cool white-8 lux	3.94c	4.25c	4.54de	4.95b	5.14e	5.53f	6.15f	6.83e
Cool white-10 lux	3.86d	4.16d	4.46f	4.63ef	5.05f	5.45g	5.84h	6.56f
Cool white-12 lux	3.76e	4.06e	4.35h	4.55g	4.94gh	5.34h	5.72i	6.45g
Red-8 lux	3.97c	4.17d	4.46ef	4.84c	5.43c	6.04c	6.54d	7.03d
Red-10 lux	4.08ab	4.34b	4.62bc	4.95b	5.61b	6.23b	6.97b	7.45b
Red-12 lux	4.13a	4.43a	4.77a	5.04a	5.72a	6.46a	7.28a	7.66a
Blue-8 lux	3.86d	4.06e	4.38gh	4.56fg	4.87hi	5.06j	5.46k	6.05j
Blue-10 lux	3.96c	4.14d	4.44fg	4.75d	5.06f	5.34h	5.82h	6.34h
Blue-12 lux	4.05b	4.24c	4.58bcd	4.91bc	5.33d	5.65e	6.05g	6.53f
Green-8 lux	3.86d	4.17d	4.44fg	4.66e	4.98fg	5.35h	6.06g	6.56f
Green-10 lux	3.86d	4.06e	4.37h	4.56fg	4.86i	5.14i	5.64j	6.23i
Green-12 lux	3.75e	3.96f	4.27i	4.45h	4.74j	4.96k	5.42k	6.02j
Yellow-8 lux	3.63f	4.04e	4.43fgh	4.83cd	5.03f	5.35h	5.85h	6.55f
Yellow-10 lux	3.76e	4.16d	4.55cd	4.95b	5.45c	5.62e	6.24e	6.81e
Yellow-12 lux	3.85d	4.24c	4.64b	5.05a	5.76a	5.95d	6.85c	7.24c
Warm white-8 lux	3.65f	3.86g	4.37gh	4.56fg	4.93ghi	5.13i	5.47k	6.04j

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Warm white-10 lux	3.54^{g}	3.78^{h}	4.26^{i}	4.44^{h}	4.86^{i}	5.05^{j}	5.32^{l}	5.87^{k}
Warm white-12 lux	3.44^{h}	3.68^{i}	4.14^{j}	4.36^{i}	4.76^{j}	4.96^{k}	5.24^{m}	5.67^{l}
SEM	±0.01	±0.01	±0.01	±0.02	±0.01	±0.02	±0.01	±0.00
Level of significance								
Light colors	0	0	0	0	0	0	0	0
Light intensity	0.02	0.2	0.04	0.02	0	0	0	0
Interaction	0	0	0	0	0	0	0	0
^{a,b,c,d} Values within a column with different superscript are significantly different (P<0.05). Data are presented as mean±SEM.								

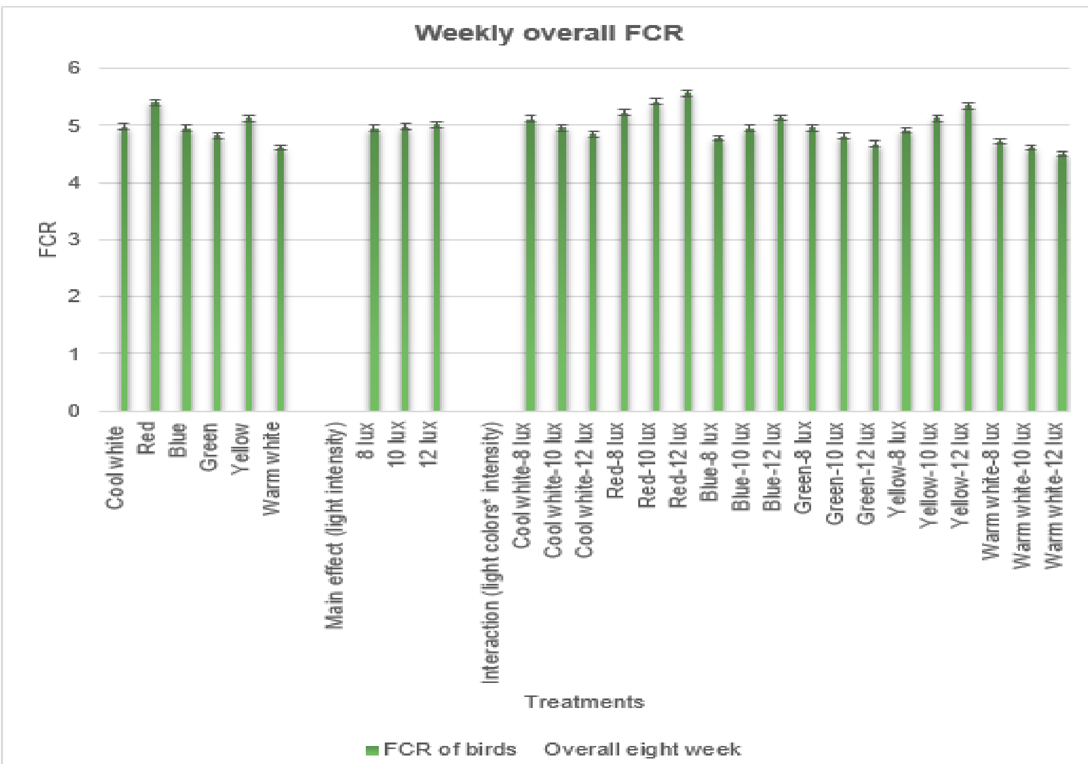

Figure 5: Effect of light color and intensity on weekly cumulative feed conversion ratio of layers (9-16 weeks)

Mortality

The data on weekly mortality in three phases of layers in (Table. 7). For the main effects of light colors, white, blue, green, and yellow lights consistently resulted in low or zero mortality rates throughout the eight-week period. Red light had the highest total mortality rate, with a noticeable increase during the last four weeks. Specifically, Red light showed a mortality rate of 0.42 during the first four weeks and 0.17 during the last four weeks, leading to a total mortality rate of 0.17. Warm white light also showed a slightly higher

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mortality rate compared to other colors, with a total of 0.08. Regarding light intensity, the study found that 8 lux and 10 lux resulted in low mortality rates across the 16th week period, with 8 lux showing no mortality in the last four weeks and a total mortality rate of 0.21. In contrast, 12 lux showed a slight increase in mortality during the last four weeks, leading to a total mortality rate of 0.33.

Table 7: Effect of light color and intensity weekly on mortality in layers (9-16 weeks)

Treatments	Mortality of birds		
	1st Four weeks	Last four week	Total eight week
Main effect (light colors)			
Cool white	0.25	0	0
Red	0.42	0.17	0.17
Blue	0.33	0	0
Green	0.17	0	0
Yellow	0.17	0	0
Warm white	0.33	0.08	0.08
SEM	±0.13	±0.05	±0.15
Main effect (light intensity)			
8 lux	0.21	0	0.21
10 lux	0.42	0	0.42
12 lux	0.21	0.13	0.33
SEM	±0.09	±0.03	±0.10
Interaction (light colors intensity)*			
Cool white-8 lux	0.25	0.00[b]	0.25
Cool white-10 lux	0.25	0.00[b]	0.25
Cool white-12 lux	0.25	0.00[b]	0.25
Red-8 lux	0.25	0.00[b]	0.25
Red-10 lux	0.5	0.00[b]	0.5
Red-12 lux	0.5	0.50[a]	1
Blue-8 lux	0.25	0.00[b]	0.25
Blue-10 lux	0.75	0.00[b]	0.75
Blue-12 lux	0	0.00[b]	0
Green-8 lux	0.25	0.00[b]	0.25
Green-10 lux	0.25	0.00[b]	0.25
Green-12 lux	0	0.00[b]	0
Yellow-8 lux	0	0.00[b]	0
Yellow-10 lux	0.25	0.00[b]	0.25
Yellow-12 lux	0.25	0.00[b]	0.25
Warm white-8 lux	0.25	0.00[b]	0.25
Warm white-10 lux	0.5	0.00[b]	0.5
Warm white-12 lux	0.25	0.25[ab]	0.5
SEM	±0.230	±0.09	±0.26
Level of significance			
Light colors	0.74	0.13	0.37
Light intensity	0.22	0.03	0.4
Interaction	0.87	0.08	0.61

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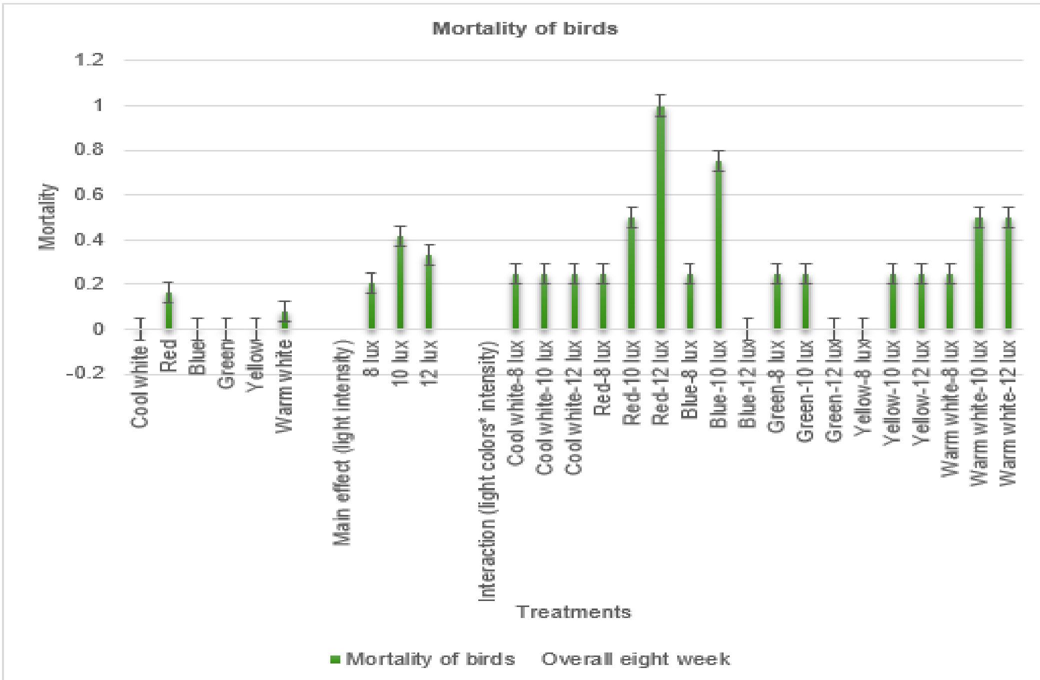

Figure 6: Effect of light color and intensity on mortality in layers (9-16 weeks)

Economics of the Experiment (9-16 weeks)

The economic evaluation of the various lights treatments is presented in (Table. 8). The results of the experiment showed that color of light, intensity of light and interaction of color and intensity of light significantly affect the cost of production of the birds at 16th weeks of age. Significantly lowest (Rs: 1063.90) cost of production was observed in the birds kept under yellow light having 12 lux intensity and highest (Rs: 1168.05) cost of production was observed in the birds kept under warm white light having 12 lux intensity.

Table 8: Effect of color and intensity of light on economic of layers (9-16 weeks)

Treatments	Economics								
	Cost of equipment and electricity	Cost of Production Per Bird (0-8 weeks)	Total feed Intake (kg/bird)	Cost of Feed (per kg/birds)	weight of bird (kg/birds)	Feed Cost per Bird	Mortality	Loss due to Mortality	Cost of Production Per Bird (9-16 weeks)
Main effect (light colors)									
Cool white	3.73^{a}	392.3	3.34^{a}	482.10^{a}	1.27^{c}	615.97^{b}	0.25	11.83	1107.2^{ab}
Red	3.73^{a}	392.51	3.36^{a}	484.15^{a}	1.18^{f}	571.33^{f}	0.58	27.91	1078.9^{b}
Blue	3.73^{a}	391.49	3.30^{b}	475.46^{b}	1.27^{d}	603.06^{d}	0.33	15.89	1097.6^{b}
Green	3.73^{a}	393.3	3.29^{b}	473.88^{b}	1.28^{b}	608.38^{c}	0.16	8.12	1096.9^{b}
Yellow	3.73^{a}	390.36	3.30^{b}	475.14^{b}	1.24^{e}	590.61^{e}	0.16	7.76	1075.9^{b}

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Warm white	1.78^{b}	393.42	3.26^{c}	469.91^{c}	1.35^{a}	635.06^{a}	0.41	19.78	1133.4^{a}
SEM	±0.00	±3.6	±0.003	±0.51	±0.001	±1.02	±0.15	±7.3	±8.05
Main effect (light intensity)									
8 lux	3.45	388.65	3.28^{c}	472.69^{c}	1.25^{c}	595.14^{b}	0.2	9.93	1080.5^{b}
10 lux	3.45	393.15	3.31^{b}	477.50^{b}	1.27^{a}	609.14^{a}	0.41	19.8	1108.9^{a}
12 lux	3.45	394.89	3.33^{a}	480.14^{a}	1.26^{b}	607.93^{a}	0.33	15.92	1105.6^{a}
SEM	±0.00	±2.5	±0.002	±0.36	±0.00	±0.72	±0.1	±5.1	±5.6
Interaction (light colors intensity)*									
Cool white-8 lux	3.73^{a}	394.36	3.26^{efg}	470.63^{efgh}	1.24^{j}	582.99^{j}	0.25	11.58	1076.1^{bc}
Cool white-10 lux	3.73^{a}	393	3.33^{c}	479.66^{c}	1.29^{ef}	619.13^{d}	0.25	11.68	1110.9^{abc}
Cool white-12 lux	3.73^{a}	389.53	3.44^{a}	496.01^{a}	1.30^{de}	645.80^{b}	0.25	12.24	1134.7^{ab}
Red-8 lux	3.73^{a}	393.71	3.372^{b}	485.39^{b}	1.22^{k}	594.36^{hi}	0.25	12.15	1087.4^{bc}
Red-10 lux	3.73^{a}	397.07	3.42^{a}	492.41^{a}	1.19^{m}	586.95^{ij}	0.5	24.22	1095.4^{bc}
Red-12 lux	3.73^{a}	386.74	3.29^{de}	474.66^{de}	1.12^{n}	532.69^{l}	1	47.37	1053.9^{c}
Blue-8 lux	3.73^{a}	385.35	3.26^{efg}	469.76^{fgh}	1.27^{g}	598.95^{h}	0.25	12.12	1083.6^{bc}
Blue-10 lux	3.73^{a}	391.1	3.27^{efg}	471.81^{efgh}	1.28^{fg}	601.68^{fgh}	0.75	35.55	1115.5^{abc}
Blue-12 lux	3.73^{a}	398.01	3.36^{b}	484.81^{b}	1.25^{hi}	608.56^{efg}	0	0	1093.7^{bc}
Green-8 lux	3.73^{a}	386.35	3.25^{g}	468.03^{h}	1.24^{ij}	582.83^{j}	0.25	12.16	1068.5^{bc}
Green-10 lux	3.73^{a}	395.1	3.28^{efg}	472.64^{efgh}	1.29^{ef}	609.36^{ef}	0.25	12.21	1103.8^{abc}
Green-12 lux	3.73^{a}	398.46	3.34^{bc}	480.96^{bc}	1.32^{c}	632.95^{c}	0	0	1118.5^{abc}
Yellow-8 lux	3.73^{a}	382.39	3.29^{e}	473.98^{def}	1.26^{h}	599.58^{gh}	0	0	1069.1^{bc}
Yellow-10 lux	3.73^{a}	392.75	3.32^{cd}	478.58^{cd}	1.26^{h}	603.01^{efgh}	0.25	11.69	1094.6^{bc}
Yellow-12 lux	3.73^{a}	395.95	3.28^{ef}	472.86^{efg}	1.20^{l}	569.22^{k}	0.25	11.61	1063.9^{bc}
Warm white-8 lux	1.78^{b}	389.72	3.25^{fg}	468.32^{gh}	1.30^{d}	612.11^{de}	0.25	11.6	1098.6^{abc}
Warm white-10 lux	1.78^{b}	389.86	3.26^{efg}	469.87^{fgh}	1.35^{b}	634.68^{c}	0.5	23.46	1133.2^{ab}

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Warm white-12 lux	1.78^{b}	400.68	3.27^{efg}	471.53^{efgh}	1.39^{a}	658.38^{a}	0.5	24.28	1168.5^{a}
SEM	±0.00	±6.3	±0.006	±0.89	±0.001	±1.77	±0.26	±12.67	±13.94
Level of significance									
Light colors	0	0.99	0	0	0	0	0.36	0.35	0
Light intensity	0.99	0.22	0	0	0	0	0.39	0.4	0
Interaction	0	0.71	0	0	0	0	0.61	0.62	0.01
^{a,b,c,d} Values within a column with different superscript are significantly different (P<0.05). Data are presented as mean±SEM.									

Analysis of Correlation and Heat-Map

The correlation analysis was drawn between the recorded growthy attributes of layers birds under the influence of various kind of light colors and intensity (Figure 7). The feed intake during the period of 9-16 weeks shows strong positive correlation while the mortality and economics shows slightly positive correlation. The body weight and weight gain slightly negative correlation with all above mentioned attributes.

The heat-map was created between the recorded growthy attributes of layers birds under the influence of various kind of light colors and intensity (Figure 8). The highest enhancement was observed in the economic, body weight (BW) and weight gain (WG) in the treatment of warm white having 12 lux light intensity while a significant reduction of these attributes in the treatment of red having 12 lux. The mortality (Mort.) and FCR attributes positively improve while body weight. Weight gain, and economics reduce in the treatment of red color having 12 lux light intensity. Principal component analysis (Figure 9) among the growth parameters under different color and intensities (9-16 weeks).

Chord graph (Figure 10) among the relationships between various growth parameters under different color and intensities (9-16 weeks). Feed Intake body weight, weight gain, feed conversion ratio (FCR), mortality and economics of the experiment. Individually treatment and parameters a given light color and intensity, with associations representing the interactions and effects on the growth parameters.

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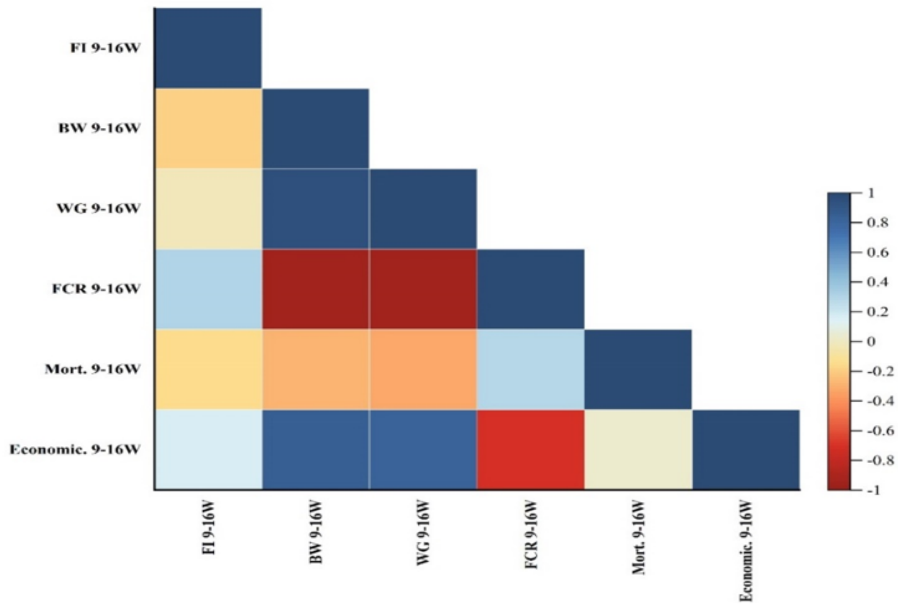

Figure 7: Analysis of Correlation among the growth parameters under the different color and intensities (9-16 weeks). Feed Intake (FI), Body weight (BW), Weight gain (WG), Feed conversion ratio (FCR), Mortality (Mort.) Economics of the Experiment (Economic)

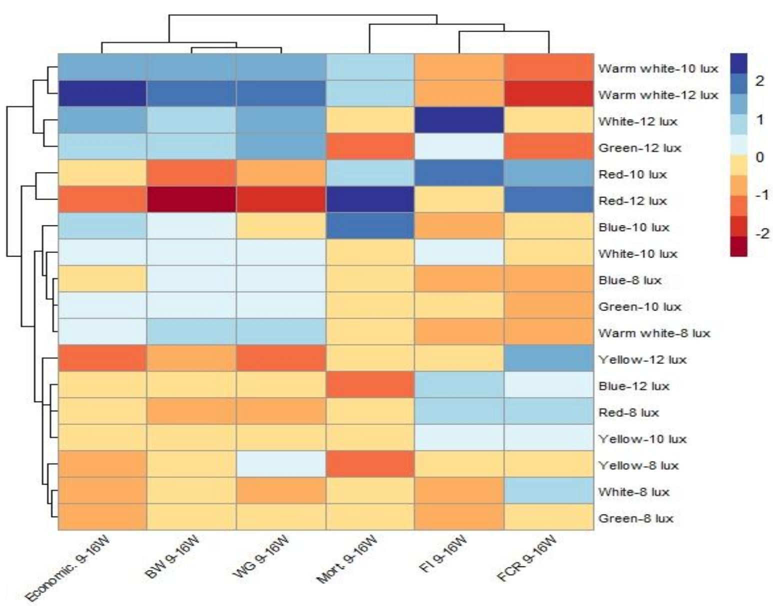

Figure 8: Heatmap among the growth parameters under the different color and intensities (9-16 weeks). Feed Intake (FI), Body weight (BW), Weight gain (WG), Feed conversion ratio (FCR), Mortality (Mort.) Economics of the Experiment (Economic)

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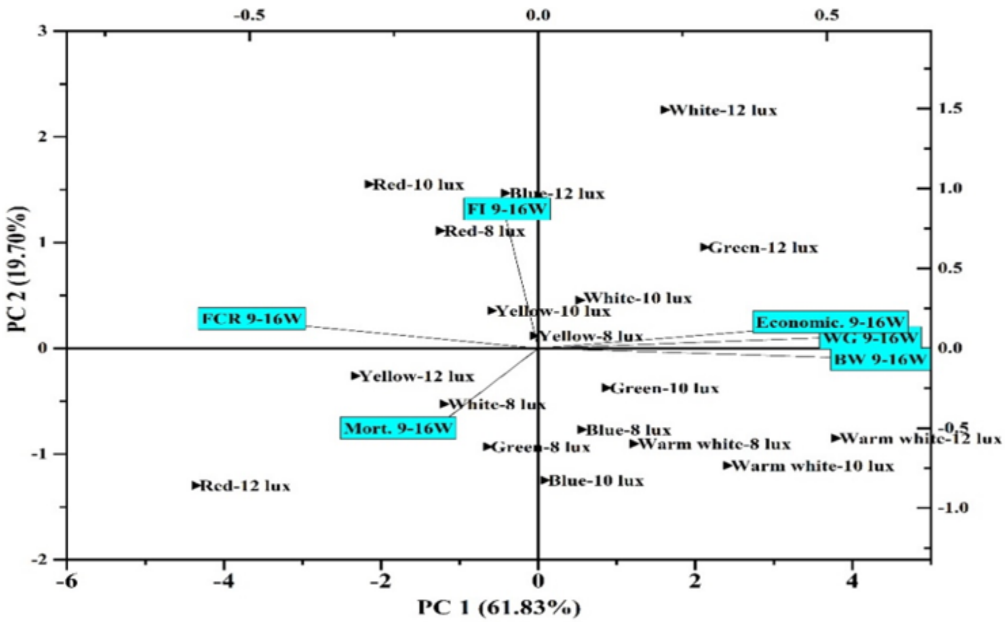

Figure 9: Principal component analysis among the growth parameters under different color and intensities (0-8 weeks). Feed Intake (FI), Body weight (BW), Weight gain (WG), Feed conversion ratio (FCR), Mortality (Mort.) Economics of the Experiment (Economic)

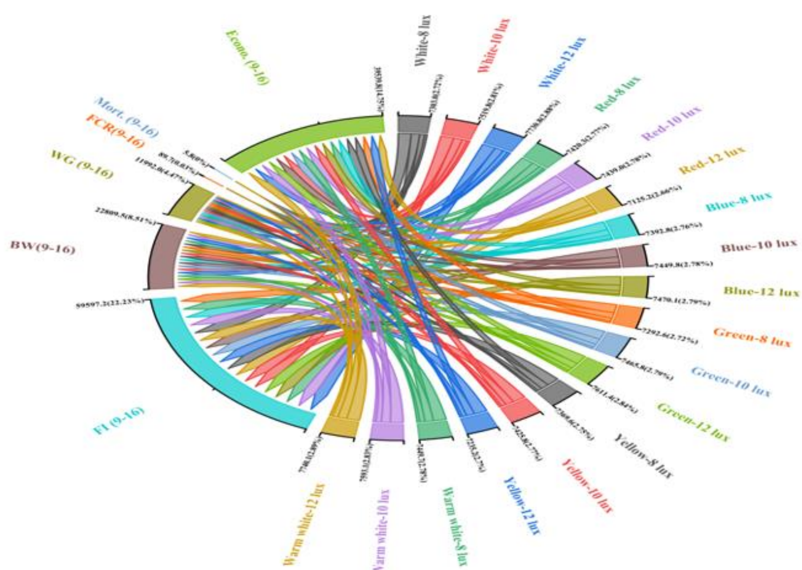

Figure 10: Chord graph among the growth parameters under different color and intensities (0-8 weeks). Feed Intake (FI), Body weight (BW), Weight gain (WG), Feed conversion ratio (FCR), Mortality (Mort.) Economics of the Experiment (Economic)

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DISCUSSIONS

Feed Intake (9-16 weeks)

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 trend of increase in feed intake with increased red and white light intensities in the experiment are in line with studies by Cherry and Barwick, (1962) and Newberry *et al*. (1988), using white light. The white light which consists mostly of long wavelength light would thus be expected to yield similar results. That birds' feed intake activity was increased in red than other light colors are in line with Prayitno *et al*. (1977) based on color effects compared with all permutations of monochromatic and mixed-color light by broilers, although this may have been affected by differences in perceived intensity of the different lights. Red light performed better at enhancing feed intake in this study, a finding which is consistent with other literature that proposed that red light enhances activity and possibly hunger or food-searching behavior (Gulizia and Downs, 2021). The red-light wavelength may be more stimulating to laying hens, as it stimulates the endocrine system, which then stimulates the hens' feeding actions. As such, the higher the light intensity, feed intake throughout the day. The treatment of 12 lux was most associated with higher feed intake relative to the other treatments. Higher light intensity treatments make hens more visible and consume more actively (Liu *et al*., 2018).

Body Weight (9-16 weeks)

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. The blue light of 12 lux also portrays significant ($P<0.05$) results. This specific intensity, together with the calming influence of blue light as has been noted by Olanrewaju *et al*. (2017), seemingly lessens stress and augments metabolic optimization to growth. The bluish light probably enhances the chicken's general well-being, resulting in increased uptake of feed and growth rates while not causing overstimulation which is created by high intensities (Deep *et al*., 2010). According to Wei *et al*. (2022), green light has been shown to mimic naturalistic conditions, promoting a tranquil environment. When red light was introduced at a lower intensity, specifically around 10 lux, the treatment resulted to be less beneficial in promoting growth. This is because such low intensity might not trigger the activity levels and feed intake enough for development (Janczak and Riber, 2015). As Lewis and Morris (2000), claimed, red light might foster the activity; however, with the intensity as low as 10 lux, it would not stimulate physiological responses enough to enhance growth.

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Weekly Weight Gain (9-16 weeks)

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 gain of the birds. The results of our experimental findings are in line with the work of Sadrzadeh *et al*. (2013) who reported that red LED light promoted no increase in body weight. Meanwhile, blue, and green light report similarly intermediate metrics with exceptional novelties in peak performance. Moreover, comparative results of our experiment are in line with Jean-Loup *et al*. (2017), who reported that very low light intensities used in the layer production cycle may lower body weights by altering behavioral patterns causing active time to decrease. Mohammed *et al*. (2016) stated that it is better to use moderate light intensity to avoid abnormal behavior. The performance of warm white light with high light intensity over various measures indicates that light quality, especially due to the absence of flicker, is essential for maximizing layers' physiological responses (Kavtarashvili and Gladin, 2022; Evans *et al*., 2012). It is likely that the stress resulting in abnormal behavior on other lights did not show in this study. These results emphasized the role of light intensity together with color. Greater intensities, mainly under 12 lux among all the colors, resulted in high weight values generally. Meanwhile, it can be confirmed with the earlier observations, which mentioned that an appropriate light intensity might help improve the chickens' visibility and activity, hence probably feeding and weight gain performances (Olanrewaju *et al*., 2017).

Feed Conversion Ratio (FCR)

The results of the experiment showed that color of light, intensity of light and interaction of color and intensity of light significantly affect the FCR of the birds. The results of our findings are line to the findings of Riaz *et al*. (2021) and Yang *et al*. (2016), who found that white light could improve FCR due to the establishment of circadian rhythms and better welfare. Moreover, red was the least efficient light in maintaining FCR, with the highest weekly value of 7.38 in the final week. The interaction between light color and intensity highlighted that warm white light at 12 lux achieved the best FCR. Conversely, red light at 12 lux had the worst FCR. Therefore, 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). 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 shows the need for optimal light intensity. The higher the intensity and especially under red and warm white lights, the more varied is

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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).

Mortality

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 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 8 lux and 10 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).

Economics of the Experiment (9-16 weeks)

The results of the experiment showed that color of light, intensity of light and interaction of color and intensity of light significantly affect the cost of production of the birds at 16th weeks of age. Significantly lowest cost of production was observed in the birds kept under yellow light having 12 lux intensity. This aligns with findings from Soliman and El-Sabrout (2020), who noted increased activity in birds under red light conditions with higher intensities, potentially leading to increased feed consumption. Meanwhile, yellow light causes cool and calm effect (Janczak and Riber, 2015). Interestingly, light at 10 lux results in the highest total cost of production poses questions about the efficiency of light management in poultry operations due to increase activity as demonstrated by Chew *et al.* (2021).

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CONCLUSION

Keeping in view the economical consideration, birds kept under red light having 12 lux shown significantly lower cost of production. It is, therefore, can be concluded that during growing phase red light having 12 lux intensity may be applied for economical layer production.

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