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IMPACT OF LIGHT WAVELENGTH ON GROWTH AND WELFARE OF BROILER CHICKENS – OVERVIEW AND FUTURE PERSPECTIVE

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Abstract

Lighting in poultry production holds notable importance with the advancement and modernization of the industry, as it plays a significant role in the physiology and growth of broiler chickens. Increasing attention has been paid to the impacts of lighting management on growth performance, immune status, and welfare of meat-type chickens. It is essential to have an appropriate lighting regimen that includes the light source, intensity, duration, and wavelength of light to improve broilers' growth and behavior. By manipulating various physiological, immunological, and behavioral activities, altering the color of light has been acknowledged as a potent managerial strategy capable of mitigating an array of stressors in broiler chickens. Assessing animal welfare is necessary for animal behavior and product quality perspectives. Birds have a unique visual system, and their behavior is primarily mediated by vision. Different monochromatic light regimes can affect feed conversion ratio, modulating broiler chickens' systematic immune response and aggressive behavior. With the advancement of lighting technology, new possibilities have emerged to enhance traditional lighting programs in poultry houses. This review integrates recent findings on the use of monochromatic light and its impact on broilers' welfare, growth, and physiological response.

Key words: monochromatic light, embryogenesis, growth, carcass quality, welfare, behaviour, broilers

The impact of farm environmental factors on the productivity of poultry has recently garnered significant attention. These factors significantly impact on broiler chickens' feed conversion efficiency and growth performance, which aid in increasing meat production to meet the demands of population growth (Gržinić et al., 2023; Zahoor et al., 2022). Worldwide meat demand is projected to increase by 40%, reaching over 400 million ton by 2030 (Soliman and El-Sabrout, 2020). In addition to relevant factors such as temperature, humidity, and ventilation, a reasonable light regimen is a crucial environmental aspect for the growth of broilers in modern farms (Lewis, 2010). Akyüz and Onbaşilar (2018) and Xie et al. (2011) have found that light color has long been recognized as a powerful management tool, capable of mitigating various stressors in broiler chickens by influencing a variety of physiological, immunological, and behavioral pathways across a wide range of light spectral ranges and wavelengths. The critical elements of monochromatic light, including color, wavelength, duration, intensity, and photoperiod length, have been identified as major influencing factors in all broiler growth cycles (Rozenboim et al., 2004). The potential application of monochromatic light and its photoperiod for improving poultry production generates increasing interest. This review explains how changes in monochromatic light affect broiler performance (Figure 1) and offers suggestions for how to boost production economically.

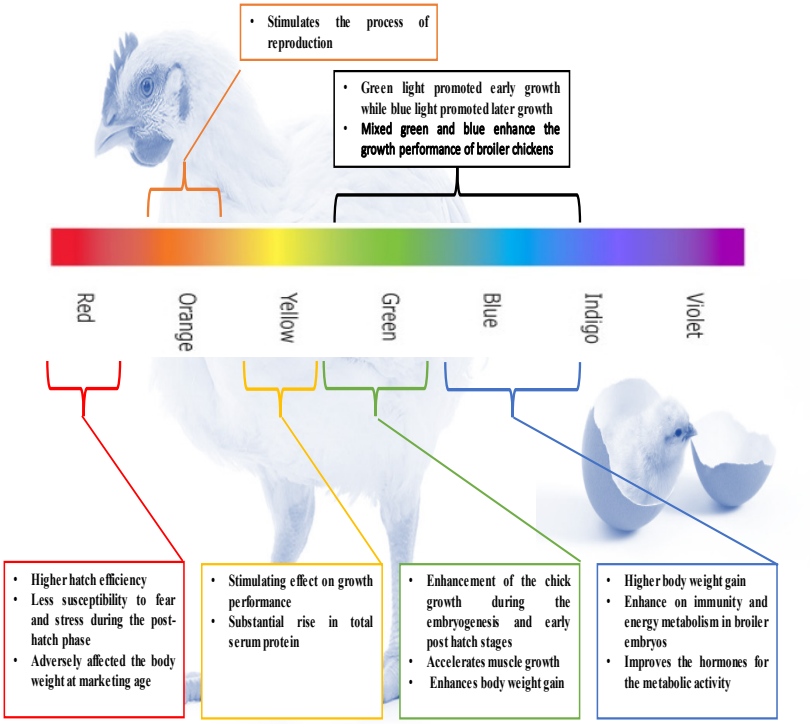


Figure 1. Effect of monochromatic light on broilers performance

Poultry vision physiology

The physiology of vision in poultry is a complex topic that is influenced by a variety of factors. The eye's actions result from anatomical, biochemical components, and physiological inducers (Egbuniwe and Ayo, 2016). Bird vision is not only affected by light color but also by duration, intensity, and wavelength (Xie et al., 2008). In poultry, three essential regions affect vision and perception of light: the retina, hypothalamus, and pineal gland (Lewis and Morris, 2006). Light enters the eyes and from the top of the skull due to extraretinal photoreceptors in the pineal gland and then goes through the pituitary. These fundamental mediators impact broilers' vision system, including light detection and transduction (Dawson et al., 2001). Rods and cones also have paramount roles in shaping the visual capabilities of these birds. More sensitive to low light conditions, rods allow poultry to perceive their surroundings even in dim or nighttime environments. These cells aid in detecting motion, ensuring awareness of potential threats, and enabling foraging behavior during twilight hours (Seifert et al., 2020). On the other hand, cones are responsible for color vision and high-resolution visual acuity in bright lighting conditions. They enable poultry to discern vibrant colors, identify food sources, and precisely navigate their environment (Seifert et al., 2020). The interplay between rods and cones allows poultry to adapt to varying light conditions, contributing to their survival and behavior in different ecological niches.

Once recognized, light information can be translated into biological signals, influencing the neuroendocrine system, particularly the hypothalamic-pituitary-gonadal axis, and thus exerting influence on circadian rhythms and other physiological functions (Figure 2) (Kuenzel et al., 2015). The pineal gland is involved in releasing important hormones such as serotonin and melatonin, which have vital roles in the circadian cycle as well as different endocrine processes, movement, and the temperature of the chicken's body. The hypothalamus gland in the brain regulates the hormone gonadotropin, homeostasis, and physiological structures based on light intensity (Baxter et al., 2014). The chicken's eyes consist of 10% of its head's entire mass, while the human's eyes consist of 1% of the whole mass of the head. The left eye of the chickens is far-sighted, but the right eye is near-sighted, which results in turning them into their egg and the right eye is exposed to light through the shell, while the left eye is not, as it is directed toward the body. The chicken has monovision, which allows them to focus on more than one object. The broiler chickens' eyes can see 300 degrees without turning their heads, whereas humans can see around 180 degrees through the eye. Additionally, chickens have a third eyelid, generally known as the nictating membrane, which slides horizontally over the eye to protect it from dust particles as well as from debris. The average length of the chick's eye axial globe is around 12–13 mm, approximately half the length of the human eye (Montiani-Ferreira et al., 2003). The sensitivity of avian eyes is reflected by the fact that the human eye, which appears to be well-equipped, contains just 40% of the optic nerve axons of chicken or pigeon eyes (Nuboer, 1993). The chicken lens has a thickness of

around 3.5 and 5.9 mm in the anterior radius of curvature (Iribarren et al., 2014). In contrast, the human lens has a thickness of around 3.9 and 10.5 mm in the anterior radius of curvature (Schachar, 2004). Poultry can process around 150–200 images per second. This highlights the importance of understanding the physiology of vision in poultry, particularly concerning the effects of light on their growth and welfare in modern poultry farms.

Poultry spectral sensitivity

Poultry have a more sensitive vision system than humans, with the ability to perceive a broader range of colors, a wider field of vision, and greater sensitivity to visual harmony (Prescott et al., 2003; Remonato Franco et al., 2022). Different wavelengths of light have various stimulatory effects on the eye retina, which induces many changes in poultry behavior and growth (Lan et al., 2013). The broiler retina has two types of photoreceptors, rods and cones, that can sense light (Wilson and Lindstrom, 2011). According to a study by Kram et al. (2010), birds have seven photoreceptor cells, including one rod and six cones, including four single cones that provide tetrachromatic color vision and double cones that are hypothesized to facilitate achromatic mobility sense (Figure 3). Tetrachromatic color vision, regulated by four distinct types of single cones, is most sensitive to violet (wavelength around 415 nm), blue (wavelength around 450 nm), green (wavelength around 550 nm), and red (wavelength around 700 nm) and brighter light, while rods are better at perceiving objects in the dark but cannot distinguish colors of light (Egbuniwe and Ayo, 2016; Jiao et al., 2014). Moreover, Parvin et al. (2014) have reported that bird's visible light wavelengths are around 380 to 740 nm, which lies between infrared (IR, with long wavelengths), and ultraviolet (UV, with short wavelengths) light beams. Lewis and Gous (2009) have concluded that humans respond to light with wavelengths around 400–750 nm, whereas the broilers can see some UV light wavelengths below 400 nm in addition to the human range. Chickens are used as animal models for studying myopia progression because they have a short developmental period and are easily handled for measuring their refractive state with retinoscopy. The spectral distribution of light color sensitivity in poultry varies with age (Classen, 2003). However, domestic fowl (poultry) vary from humans in spectrum sensitivity, and this difference highlights the need to find the ideal light environment for broiler chicken development, performance, health status, behavior, welfare, and productivity.

Monochromatic light: Definition and specialized effects

Monochromatic light, also known as light that has a single wavelength, is a form of electromagnetic wave radiation that appears as a single color to the retina (Rucker, 2019). The term "monochromatic" is derived from the Greek words "monos," meaning "one," and "chromos," meaning "color". This type of light is commonly used in the infrared (IR) and ultraviolet (UV) ranges, as well as in the visible spectrum. It is well-known that the majority of commercial poultry production relies on controlled environments in which artificial lighting is used to manage the growth, behavior, and quality of birds (Rana and Campbell, 2021).

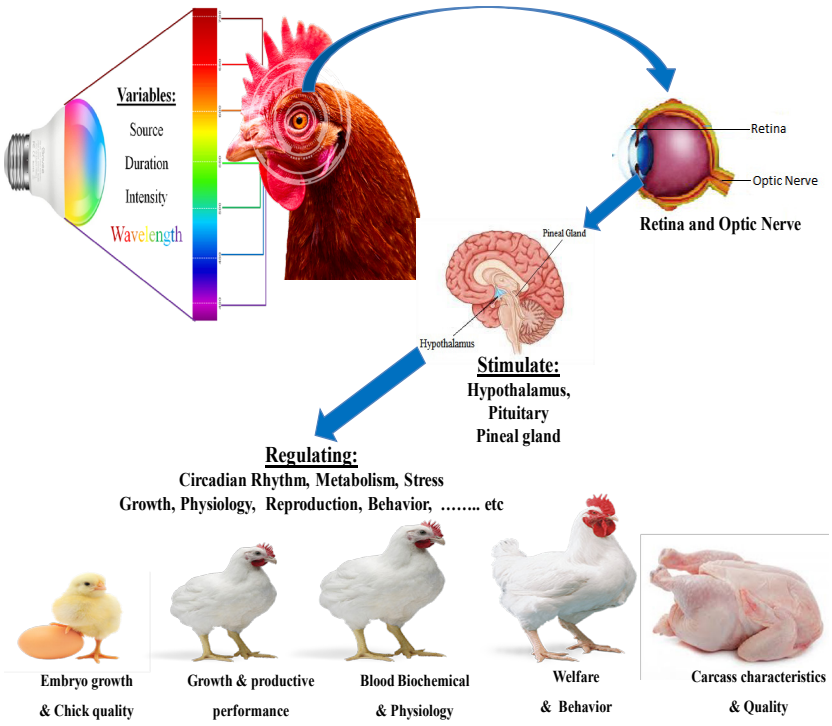


Figure 2. Effect of monochromatic light on the neuroendocrine system of broiler chickens

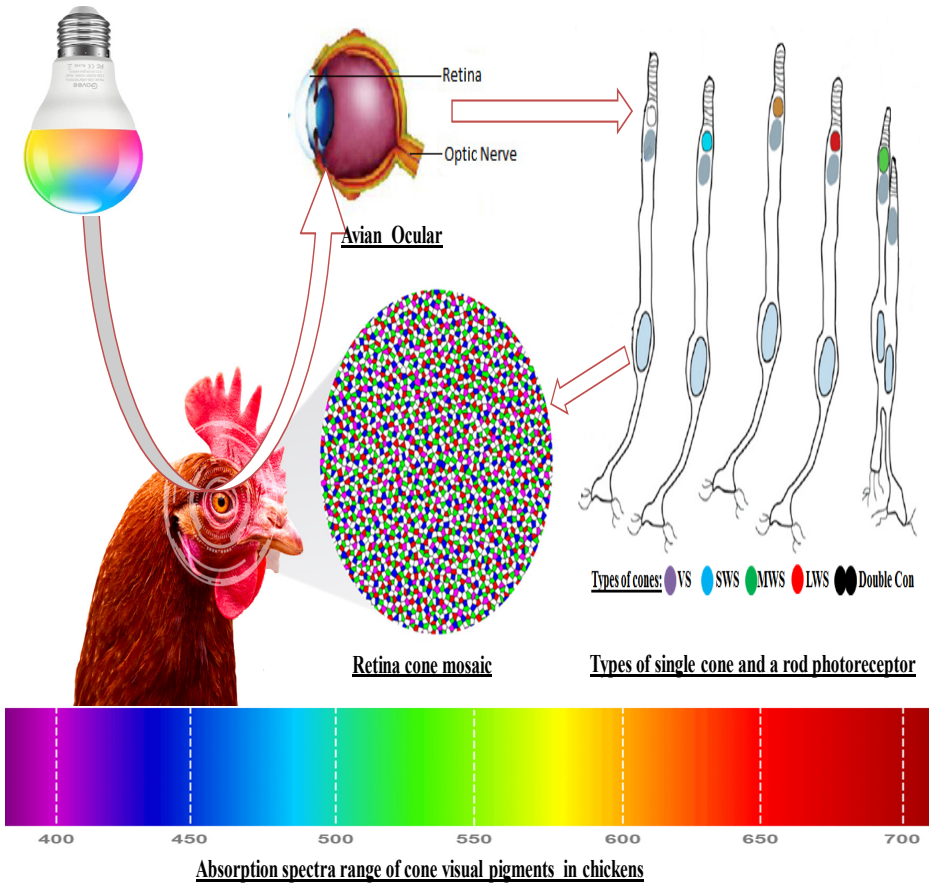


Figure 3. The photoreceptors involved in poultry vision: VS, violet-sensitive; SWS, short wavelength-sensitive; MWS, middle wavelength-sensitive; LWS, long wavelength-sensitive

Different light sources are used in poultry farming, including fluorescent, metal halide, incandescent, high-pressure sodium, compact fluorescent, and light-emitting diodes (LEDs). Historically, incandescent light bulbs (ICDs) have been widely used in poultry farms across the world (Lewis and Morris, 1998). However, due to their high energy consumption, ICD light bulbs have been phased out of the market in poultry houses (Sissine, 2007; Soliman and El-Sabrout, 2020).

Lighting technologies, such as cold cathode fluorescent lamps (CCFLs), compact fluorescent lamps (CFLs), and LEDs, have emerged as promising replacements for ICDs due to their energy efficiency, extended lifespan, moisture resistance, and wide range of peak wavelengths of light output (Chang and Lu, 2013; Mills and Jacobson, 2011; Olanrewaju et al., 2018). LEDs are particularly popular among poultry producers due to their many advantages over traditional incandescent and fluorescent light bulbs. They are more energy efficient and have a longer lifespan, as well as a broader range of colors that can enhance productivity (Cao et al., 2012; El-Sabrout and Khalil, 2017; Hassan et al., 2014 b; Parvin et al., 2014).

UV light is gaining popularity in poultry farming to improve welfare and optimize productivity. The importance of UV light in poultry house management is based on simulating nature, particularly those seen in open houses with natural and tropical lighting conditions (Guevara et al., 2015). The three unique elements of UV light are UVA (316–400 nm), UVB (281–315 nm), and UVC (100–280 nm), which make up the shorter wavelengths of the electromagnetic radiation spectrum (100–400 nm). A poultry's eye lens may perceive UVA light because of its visual perception of radiation between 320 and 400 nm (Hunt et al., 2009). Moreover, broilers reared under UV light have lower stress susceptibility and fear responses, which may be critical to maximizing the welfare and growth performance of broilers (Wu et al., 2022).

UVB wavelengths have a physiological influence by stimulating vitamin D pathways, promoting skeletal health, and reducing the occurrence of tibial dyschondroplasia and rickets, which are commonly found in male broilers (Mo et al., 2023; Rana and Campbell, 2021). Additionally, UVB light can improve bone mineral density, thereby enhancing the production of poultry eggs and increasing the vitamin D levels in the egg yolk (Wei et al., 2020). The vitamin D metabolites such as hydroxycholecalciferol have been shown to improve feed efficiency, enhance body weight, and to improve breast meat yield under various conditions (Fritts and Waldroup,

2003, 2005; Yarger et al., 1995). Artificial UVA illumination has been shown to impact chicken behavior positively (Kristensen et al., 2007). Furthermore, when the UVA and UVB light treatments are combined, the growth rate of chickens improves, indicating that UV wavelengths have the ability to boost the growth and performance factor of male broiler chickens (Rozenboim et al., 2004).

Monochromatic light and broiler performance

Performance during embryogenesis

The significance of light in the incubation process is logical, as hens in the wild occasionally leave the nest to consume food and water, and embryos as early as three days after conception can respond to light. During embryonic growth, light conditions are a crucial factor that can affect embryogenesis and post-hatch chick performance (Karim, 2017). Factors that may affect the outcome of utilizing lighting in incubators include the source, color, and intensity of the light, the size of the egg, and the properties of the eggshell (Hluchý et al., 2012). Studies have found that supplying light during embryogenesis does not negatively affect chick performance or health and may have potential advantages in reducing stress associated with growth (Archer et al., 2009). Hluchý et al. (2012) found that red light has a higher hatchability rate than blue light, while white light exhibits the highest average hatchability. The time of light exposure and the lighting hours are both crucial limitations for the efficacy of lighting during incubation, as they significantly influence the embryo's physiological features, hatchability, chick quality, and post-hatch performance.

Numerous studies have investigated the effect of monochromatic light supplementation during incubation on embryonic growth and chick quality at hatching. The best condition for the incubation process should be maintained to achieve high efficiency in hatchability (Table 1). For instance, Wang et al. (2020) reported that monochromatic green light stimulation shortened the hatching time and improved the post-hatch body weight and breast muscle growth of broilers without affecting the hatch window, peak hatching period, and hatchability of White Leghorn, Rhode Island Red, Columbia Rock, and Barred Rock layer breeder strains. Moreover, Zhang et al. (2016) determined that using green LED light during incubation has the potential to improve chick development throughout embryogenesis and the early post-hatch periods. Similarly, Shafey and Al-Mohsen (2002) found that exposing Hybro meat-type breeder eggs to continuous green light during the first 18 days of incubation increased embryo weight and chick weight at hatch by about 37%, and accelerated hatching time by about 24 h when compared to a control group exposed to darkness. These findings are in agreement with those of Akyüz and Onbaşilar (2018), Drozdova et al. (2019), El-Sabrout and Khalil (2017), Ozkan and Simsek (2022), and Wang et al. (2020).

Furthermore, Li et al. (2021) found that providing monochromatic blue light during incubation improved the production parameters of broilers during the first week post-hatch. Additionally, providing a mixture of white and red light during embryonic development has been linked to higher hatchery efficiency, reduced susceptibility to fear and stress during the post-hatch phase, and improved animal welfare (Archer, 2017). More recently, Abd El Naby et al. (2021) have recommended using red or blue light to improve hatchability. Abdulateef et al. (2021) also have found that using red light, blue light, and especially green light during the embryonic period positively affects the development of the embryo and chick quality traits.

The mechanisms by which monochromatic light affects broiler performance during embryogenesis still need to be fully understood. However, light is thought to influence the secretion of hormones and other signaling molecules that regulate growth and development. One mechanism by which monochromatic light can affect broiler performance is activating of the somatotropic axis. The somatotropic axis is a complex hormone system that regulates growth and development. Monochromatic light has been shown to increase the activity of the somatotropic axis, which can lead to improved growth and development (Dishon et al., 2021 a). Additionally, Wang et al. (2020) found that monochromatic green light stimulation during embryogenesis up-regulated the expression of genes involved in muscle growth. Monochromatic light can also affect cell signaling, leading to changes in cell growth and differentiation (Mohamed et al., 2020). More research is needed to fully understand these mechanisms, as the potential benefits of using monochromatic light to improve broiler performance are promising.

Performance during the rearing period

The potential of chickens can be maximally expressed when raised under optimal environmental conditions, with factors such as ecological management and lighting quality that are playing a significant role in determining their efficiency and production improvement. Numerous studies have been conducted to investigate the impact of monochromatic light on broiler growth and productive performance, as outlined in Table 2. It has been observed that rearing broiler chicks under blue and green light increases their body weight, whereas red light has an adverse effect on their body weight at the marketing age. Furthermore, research has shown that feed intake and feed conversion ratio are highest when broiler chickens are exposed to red light, while green light accelerates muscle growth at an early rearing stage (El-Sabrout et al., 2022; Halevy et al., 1998). Mixed green and blue wavelengths have been found to improve broiler chicken performance (Yang et al., 2016 a), and exposure to reddish-orange light has been found to stimulate the reproductive process in broiler chickens (Rozenboim et al., 2004).

Table 1. Effect of different light wavelengths on embryonic performance of broiler chickens

Treatments	Species	Findings	Conclusion	References
3 groups: dark (D), red (RL), and blue (BL) LED during the 25-day incubation phase	1500 Black Bronze turkey eggs	RL and BL significantly affected hatching capability. RL and BL significantly affected the expression of muscle growth-related genes in hatchling. Red or blue LED light significantly affected mortality rate.	Use of red or blue light can enhance hatchability through up-regulating the expression of muscle growth-related genes.	Abd El Naby et al. (2021)
4 treatments: dark (D), lights of red (RL), blue (BL), and green (GL).	300 fertile Ross 308 eggs	RL, BL, and especially GL significantly increased embryo weight, chick weight, and hatchability. Increased neurophysiological characteristics of the neurons, higher brain weight, and increased brain index in RL, BL, and notably in GL	Using of RL, BL, and especially GL light during the embryonic period influences embryonic development and the neurophysiological measures.	Abdulateef et al. (2021)
12L:12D cycle under white, red, green or blue light	450 eggs of Ross 308 broiler breeder	RL and WL light increased pineal melatonin level and lower level under GL. BL resulted in the lowest melatonin biosynthesis.	The chick embryo's ability to distinguish between different light wavelengths.	Drozdova et al. (2019).
4 lighting treatments: (dark, white, red, or blue) for 12 h.	About 7000 eggs of Ross 308 broiler	Not a single variation was discovered in terms of embryonic development or hatch window, embryonic survival, hatchling weight, chick length, navel sealing, or spleen weight. The average air cell temperature was lower in the red group than in the dark, white, or blue light groups.	The use of red, white, and blue light during incubation had no negative effects on hatchability, day-old chick quality, or embryo mortality. These lights, however, may have an effect on immune and energy efficiency in broiler embryos.	Li et al. (2021).
Incubation in dark (D) or continuous green light (GL) during the first 18 days.	798 Hybrobroiler breeder eggs	GL significantly increased weight, dead embryo percentage, and chick weight at hatch by about 37% and 2%, respectively. When compared to the D-control, GL accelerated hatching time by around 24 hours.	Chick weight on the day of hatch, embryonic development and hatchability were all improved by the use of GL throughout incubation.	Shafey and Al-Mohsen (2002)
Incubated under (12L:12D, green light group) or (0L:24D, dark group) for 18 days	2400 eggs of 4 strains of layer breeder eggs	GL did not extend hatch window and peak hatching period GL increased BW of Rhode Island Red only that of the dark group at 8 to 12 wk of age.	When embryos are stimulated with green light (12L:12D) during embryonic development, the hatching time is reduced without affecting the hatching or post-hatch performance.	Wang et al. (2020)
Incubated under (12L:12D, green light group) or (0L:24D, dark group) for 18 days	600 eggs of White Leghorn	A shorter hatching time was achieved with the use of GL without affecting the hatchability or hatch window.	Incubation with monochromatic green light (12L:12D) decreased hatching time without affecting hatching performance.	Wang et al. (2021)
3 lighting groups: continuous white light, green light and dark.	480 fertile eggs of Arbor Acres	GL and WL had no effect on the weight loss % of viable eggs, hatching time, hatchability, chick embryo or body weight (BW), or the weight percentage of heart, liver, and eyes. At 3 and 6 days after hatching, the percentage of pectoral muscle in the BW was raised by GL throughout incubation. As compared to dark or white embryos, GL embryos exhibited a lower weight percent of yolk retention on 19 days of development and one day post-hatch in comparison.	Using green LED light during incubation to boost chick post-hatch development has the potential to be useful.	Zhang et al. (2016)

Table 2. Effect of different light wavelengths on productive, physiological performance and welfare of broiler chickens

Light treatments	Strain	Findings	Conclusion	References
1	2	3	4	5
ICL: Incandescent light WL: White light LED RL: Red light LED BL: Blue light LED GL: Green light LED ML: Mixed light LED	Ross 308	LED-BL exhibited higher productive performance (highest livability % and EPEF). LED-BL exhibited less fear and stress response (low corticosterone, increased melatonin). LED-BL improved lymphoid organ weights and immunity titer.	Applying LED-BL in broiler house is preferable and showed significant positive effects on productive and physiological performance compared with other light colors.	Abdelazeem (2019)
White light (WL), blue light (BL), WL + heat stress, BL + heat stress	Ross 308 and Cobb 500	BL under heat stress lowered MDA while increasing SOD, CAT, and gene expression. As a result of heat stress, BL decreased degenerative alterations in liver tissue. BL influenced the expression of HSP70, HSP90, HSF1, and HSF3 genes in the livers of Ross and Cobb chickens.	Using blue light improved most assessed parameters under heat stress.	Abdo et al. (2017)
CL: Cool LED WL: Warm LED	Cobb 500	CL birds had heavier weight, better FCR. CL birds had lower ASYM, CORT, HL. CL birds had faster TI, flapped less INV, vocalized less during ISO, when compared with WL birds.	COOL LED is not only important for production, but also for welfare of the birds.	Archer (2017)
White light color (WL) Green light color (GL) Blue light color (BL) Cycling green to blue (G-BL)	Cobb chicks	G-BL gets highest LBW and BWG then BL, GL and WL, respectively. G-BL gets lowest FI and mortality % then BL, GL, and WL, respectively. G-BL gets highest and economic FCR. G-BL highest time spent in rest and sleep while WL lowest time in rest and sleep. Light colors had no effect in preening and wing flapping. WL highest values in ground pecking and tonic immobility (TI).	Cycling between green and blue light colors gets high growth performance with low cost and low vices and improves welfare.	Balabel et al. (2017)
Neon (Control) Neutral LED Cool LED Warm LED	Ross 508	Warm LED negatively affects LBW and carcass weight. The use of LED lighting has no influence on carcass yield. Neutral and cool LEDs have greater drip loss percentages. The warm LED increased PUFA levels, however the PUFA/SFA ratio did not change.	LED light enabled for considerable cost reductions in chicken farming without affecting production indices or product quality.	Bennato et al. (2021)
GLED: green monochromatic LED WF: white fluorescent lamp	Ross 308	Female BW higher in green LED vs WF fluorescent lamp. Green LED promoted higher EEI in males and females compared to WF fluorescent lamp there were no changes in BWG, FCR, and mortality %.	Green monochromatic LED illumination can be used to augment male broilers grown in open houses with natural light.	Guevara et al. (2015)

Table 2 – contd.

1	2	3	4	5
Red (R), yellow (Y), green (G), blue (B), and a combination of RY, YG, and GB light. Control is fluorescent white.	Ross×Ross broiler chicks	G and G×B increased BWG at 3 wks. B and G×B had higher FBW, BWG at 4–5 wks. B and the G×B raised the pH of the meat, lowered the shear force, and L *. B reduced blood glucose, HDL and LDL levels. Y and G increased levels of IgG and IgA at 21 days. B light increased IgG and IgA at 35 days.	When compared to monochromatic G or B light, mixing GB light improved broiler chick development and immunity.	Hassan et al. (2013)
8 treatments were used: red (R), green (G), blue (B), and combinations of red green (RG), red blue (RB), red green blue (RGB), and RBG light colors, with fluorescent white (FW) as a control.	Ross 308 broiler chicks	G birds were heavier in LBW and WG during the first 1–3 weeks. RBG, RG and B and G were heavier respectively at 4–5 weeks. RG increased breast meat pH. RG and RBG had higher bone mineral density of the tibia. RG and RBG had higher serum glucose content.	For broilers, the use of monochromatic G and B and the combination RG and RBG is preferable.	Hassan et al. (2016)
There were six treatments available: pure blue (PB), bright blue (BB), sky blue (SB), greenish blue (GB), green (G), and white (W)	Ross 308 broiler chicks	SB was heavier in LBW and WG during 8–21 days. PB was heavier in LBW (22–42 days). PB light reduced blood glucose, T. protein, Tri.G, T. cholesterol and HDL levels.	PB and SB light enhanced growth performance, blood and meat quality.	Hassan et al. (2016)
LED light: (white, WL), (blue, BL) and (green, GL)	Ross 308 broilers	The BL and GL groups were heavier than the WL group. GL and BL broilers kept eating more feed than WL broilers. The color of the LED had no effect on the length of tonic immobility. At day 28, there was no discernible variation in gait score. GL improves their walking abilities IGF-1 levels were greatest in WL. ACTH levels were lower in BL and GL than in WL.	BL and GL enhanced broiler body weight and stress reactivity, whereas GL increased walking ability.	Helva et al. (2019)
Light color (yellow, red, green and blue)	Fayoumi	BL: highest eating frequency. GL: highest preening, dust bathing and drinking. RL: increased activity (more walking, flying, head movement, litter scratching, body shaking, wing flapping, wing/leg stretching, feather pecking, and aggression). BL: the birds were the calmest (sleeping, sitting and idling behaviors). BL: improved plumage condition, foot and toe health, and growth performance.	The blue light color may improve the bird welfare.	Hesham et al. (2018)
White, blue, green and red LED bulbs	Broiler chicken	FBW was BL, WL, RL and GL. FCR was GL, RL, WL and BL. Carcass weight was BL, WL, RL and GL. IgY was RL, GL, WL and BL, respectively.	BL attained higher FBW and red light may enhance the immune without adversely affecting broiler performance.	Hogshead (2015)

Table 2 – contd.

1	2	3	4	5
(C) White LED control (A) C + UVA (UVA only) (B) C + UVA and UVB (UVA+UVB)	Ross 308	When compared to C, UVA feathers had better condition. UVA exposure exhibited shorter TI durations than C, indicating less fearfulness. When compared to the control (C), UVA (A) and UVA+UVB (B) exhibited higher Bristol Gait Scores. .	Modification of LED light to incorporate UVA wavelengths for broilers had a significant positive effect on bird welfare.	James et al. (2018)
Exposed to: white light (WL), red light (RL), green light (GL) or blue light (BL).	Arbor Acre male broilers	The rhythm of cCry2 was frequently disrupted by RL. All clock genes were promoted by RL. All clock genes were delayed by GL. GL decreased both parameters of negative clock genes, but RL demonstrated the reverse tendency. Melatonin levels were higher in GL and lower in RL.	GL may increase the expression of positive clock genes, which may lead to the formation of melatonin. RL may increase the expression of negative clock genes and reduce the production of melatonin.	Jiang et al. (2016)
Different LED color: (white LED, green LED, blue LED and red LED)	Cobb 500 chicks	Not significant in DWG and WG, DFC and TFC, FCR and mortality %. Not significant in performance for the trial. Not significant for carcass yield, fat %, pectoralis major, total pectoralis, thigh, wing or leg as % of BW.	-	Leigh et al. (2017)
C1: LED white (400–760 nm) C2: LED blue/green (470–525 nm).	Cobb 500 strain	C2: blue/green had more comfort behaviors and calmer than those exposed to white light. C1: LED white had higher aggressive behavior and discomfort.	The LED blue/green color revealed more significant comfort behavior, indicating improved welfare.	Lucena et al. (2020)
WL from 0–34 days, From 35 to 49 days: WL and BL.	Cobb broiler chicks	BL increased FBW and reduced weight loss %. BL: TI duration, RR, H/L ratio, IL-1β and internal organs weight were significantly lower.	BL may be a good tool for improving welfare and mitigating stress.	Mohamed et al. (2014)
Different LED color: (white, green and blue)	Avian 48 broiler	Blue and green LED groups had higher LBW, BWG, FC, carcass (g or %) and better FCR. Blue and green LED groups had higher Hb, RBCs, PCV, TLC, lymphocytes, T. protein, Alb., Glob. Blue and green LED groups had lower bursa, liver, spleen % weight, H/L ratio, GOT, GPT compared with white light. Blue and green LED groups showed short TI duration and high levels of exploration in the open field test.	Rearing broilers under blue and green LED light improved growth performance, physiological response, welfare, reduced stress and fear responses.	Mohamed et al. (2017)
4 LED light colors: (WL, GL, BL and GL/BL)	Cobb Avian-48	Final BW, BWG and FCR. RBCs, PCV and hemoglobin T. protein and albumin. GPT and GOT was higher in GL/BL, BL, GL and WL, respectively. Duration of TI, mobility, immobility, immobility sitting, immobility standing were better in GL/BL, BL and GL than in WL group.	LED light (GL/BL, BL and GL) may be used in broiler houses to boost the health and well-being of the chickens.	Mohamed et al. (2020)
WL: white light RL: red light BL: blue light GL: green light BGL: mixed blue/green	Ross 308	Increased T. protein and albumin under BGL. Increased globulin under GL. Increased uric acid under BL and increased triglyceride under GL. No effect on glucose, cholesterol, HDL and LDL.	BGL gave an advantage in the blood measurements compared with those raised under other light programs.	Tabeekh (2016)

Table 2 – contd.

1	2	3	4	5
White (WH), green (GR), blue (BL), GR→BL (GB), BL→GR (BG), BL→GR (BGG) and GR→BL (GBB)	Arbor acre male chicks	GBB and GB were higher in FWB. WH and BG were higher in FC. WH gets worst FCR. GR and BL had higher plasma T3. WH was higher in H/L ratio than BG, GR, BGG, GB and GBB. WH, BL and BG get lowest breast muscle compared to GBB, GB, BGG and GR.	The combination of GL and BL boosted broiler chicken development, and modulation of light color can be utilized to enhance chicken welfare and performance.	Oke et al. (2021)
Different wavelengths: (blue, green, yellow and white)	Cobb chicks	Male broilers raised in GL exhibit natural behavior. Blue light was more important in the behavior of male broilers.	Blue and green lights influenced male broiler behavior, boosting their attendance at the bird feeder and decreasing their idleness period.	José Paixão et al. (2022)
Using LEDs, there were six groups: pure blue (PB), brilliant blue (BB), sky blue (SB), green blue (GB), pure green (PG), or white (W).	Ross broilers chicks	The PB group had the most LBW, followed by the BB group, than the W group. Splenocytes were significantly increased in PB and BB. Peripheral blood mononuclear cells were significantly increased in BB. BB significantly increased nitric oxide generation and macrophage activation.	Shorter wavelength LEDs such as PB and BB can improve immune function and growth of broilers.	Seo et al. (2015)
White (Control), Red (RL), green (GL) and blue (BL)	Ross 308	Highest MDA value in RL. All antioxidant parameters were highest in GL. SOD and GPx were higher in GL than BL.	Red light may be a stressor, but GL may be a positive stimulus for broiler development, oxidant-antioxidant equilibrium, and homeostasis.	Seyidoğlu et al. (2020)
Interval (4L:2D, 4 times) illumination using red, blue, and white LED lights.	Ross broiler chicks	Blue LED significantly increased LBW, BWG, PI, CW, spleen, heart, and liver weights, and anti-ND antibody titer. Blue LED significantly declined FC, WI, GLUCO, TG, TC, GH, T3, T4, total bacterial count (TBC), and total *Enterobacteriaceae* count compared to RL and WL	The blue LED light is highly recommended for enhancing the productive performance, growth, and immunity.	Soliman and Hassan (2019)
Five color LED light: WL as a control, RL, BL, GL, and B*G mixed light	Ross 308 broiler chicks	WL recorded higher feeding. RL recorded higher eating together. GL increased drinking. GL higher in walking and standing. RL and WL recorded higher feather pecking and aggressive. BGL recorded higher sitting.	Broilers raised under RL and WL were more active than those raised under BL and GL.	Tabeekh (2016)
5 light treatments: (F) fluorescent lights (G) green LED (B) blue LED (G-B) green and blue LED (GxB) green-blue-dual-wavelength LED	Meihuang Chinese-native broiler	Green/blue LED (G-B and G×B) increased LBW then single (G and B) compared with normal artificial light (F). Carcass was greater in (G×B) when compared with the single light (G or B). (G-B and G×B) significantly improved FCR compared with (F). FCR were higher in mixed light (G×B) than in single LED G or B. G group a greater HDL level than B group. B group resulted in greater LDL cholesterol level than G group. (G-B and G×B) increased glucose level than (G or B).	Using mixed LED light G and B can be applied as an excellent technique for optimizing the growth of chickens.	Yang et al. (2016 a)

Table 2 – contd.

1	2	3	4	5
Seven groups: red (R), yellow (Y), green (G), blue (B), purple (P), white (W), and incandescent (I).	yellow-feathered broiler chicken	Y, G, and B had higher LBW. Y group had greater RGR than other groups, particularly those in the I group. R group had higher WC and FC and Y was lowest. Y group produced the lowest amount of manure.	Poultry industry can benefit from the use of yellow LED lights.	Yang et al. (2016 b)

To fully express their genetic growth potential, broiler chickens must be provided with the best possible environment (Kalia et al., 2017; Vasdal et al., 2022). A study conducted by Cao et al. (2008) examined the effects of rearing broiler chickens under various lighting conditions, including red, white, blue, and green. The results demonstrated that broilers grown under blue light had higher body weight gain (BWG) compared to those grown under green light. Interestingly, Zhang et al. (2012) and Jiang et al. (2012) reported that green light enhances BWG more than blue light, and further growth enhancement was observed by changing green to blue light color during the rearing period. Kim et al. (2013) concluded that broiler growth was increased when raised under short light wavelengths such as green and blue; however, yellow light showed some stimulating effect on growth performance. Green light exposure has been found to promote changes during the early stages of the broiler chicken development, while blue light exposure enhances growth during later stages of development (Cao et al., 2008, 2012; Rozenboim et al., 2004).

A number of studies have investigated the effects of different colors of light on the growth and productivity of broiler chickens. Soliman and Hassan (2019) observed that blue LED light improves the hormones associated with metabolic activity and increases the productivity and carcass weight of broilers. However, other studies have found mixed results. For example, Rozenboim et al. (1999) found that broilers grown under green lighting had high body weight in the first two weeks but were associated with a higher mortality rate.

Contrarily, some evidence shows the significant effect of red light, as Atapattu and Wickramasinghe (2007) found that broiler chickens reared under red light had a high body weight and feed conversion ratio. James et al. (2018) also found that broiler chicken weights increased when reared under the red light and helped to reduce bird terror. However, Classen (2004) found that red light enhanced growth when used only at the early rearing period, but that growth rate was reduced when applied at a later stage. When exposed to red or red-yellow lights, broilers become more agitated and fearful, whereas blue or green-blue lights lowered their activity (Sultana et al., 2013). On the other hand, in the case of the Hybro broiler chicken, the weight of the chicken body, feed intake (FI), water consumption patterns, and feed conversion ratio were not significantly affected by red and white color during nighttime (Senaratna et al., 2008). Meanwhile, a meta-analysis study by Lewis and Morris (2000) found that the growth rate of broiler chickens under white light and red color light exposure was the same and suggested using longer wavelengths for suppressing growth rather than promoting growth with shorter wavelengths.

Recent studies have also focused on the synergetic effects of different combined monochromatic light during the growing period of broilers, as several recommended mixing green and blue light to enhance the growth performance, welfare, and immunity of broiler chicks (Balabel et al.,

2017; Dishon et al., 2021 b; Wu et al., 2022; Yang et al., 2016 a). Overall, these studies indicate that the growth performance of broilers (body weight, weight gain, feed conversion, feed conversion ratio, and livability) is significantly better in groups treated with LED light than those treated with incandescent light. Additionally, raising broiler chickens in the short light wavelengths (green and blue) separately or combined has been shown to affect growth performance parameters of broiler chicks positively.

Mortality

The physiological and productive performance of poultry is greatly influenced by lighting, and the mortality rate is a key indicator for ensuring parameter optimization (Hogshead, 2015; Khosravinia, 2007; Olanrewaju et al., 2011). Many studies have shown that the wavelength of light does not have an impact on poultry mortality rates (Cao et al., 2008; Lewis and Morris, 2000; Mendes et al., 2013; Rogers et al., 2015; Rozenboim et al., 2004; Wabeck and Skoglund, 1974). For example, the mortality rates of broilers grown under white, green, blue, or red lighting were not found to be significantly different (Rozenboim et al., 1999). A study on the effect of green light on the mortality rate of broilers showed that green light led to lower mortality rates in birds aged 10 and 40 weeks compared to those raised under white light (Cave, 1990). Franco et al. (2022 a) reported that mortality only differed at five weeks of age, as broilers raised under white light recorded higher mortality than those raised under blue. Contrarily, at day 42 of age, the mortality rate of chickens reared under green fluorescent light was 8.87% (Hakan and Ali, 2005), which was significantly higher than the mortality rate seen in experiments using other types of light (cold white fluorescent, white thermal lamp, and green LED). Regarding UV monochromatic light, it has been observed that supplementary UVA exposure for an 18-hour photoperiod led to a 75% reduction in mortality for chickens compared to a control group with no UVA wavelengths. However, it should be noted that male chickens may be more susceptible to sudden death syndrome when treated with UVA (Olkowski and Classen, 1998).

Carcass characteristics and meat quality

Exanimating the effects of different light colors on the meat quality and chemical composition of broiler chickens during the growth phase is an important aspect to consider, particularly for customers. However, there have been limited studies conducted in this area. In this context, different wavelengths of light have distinct impacts on growth rate (Hogshead, 2015; Olanrewaju et al., 2011). Moreover, Liu et al. (2008) reported increased absolute and relative weights of breast and thigh muscles in broiler chickens exposed to blue or green light compared to red and white light at the marketing age of 49 days. Furthermore, Liu et al. (2010) found that the breast muscle weight of broilers raised under green light was greater than that of birds reared under blue, red, and white light. Additionally, Mosa et al. (2014) showed that broiler carcass weight, dressing, thigh muscle, and breast muscle percentages significantly increased at 35 days when exposed to blue-green light. Furthermore, Yang et al. (2016 b) found that the percentage of the carcass was significantly improved for broilers exposed to green-blue mixed light, when compared with broilers exposed to single light. On the other hand, different LED lighting colors, such as red, yellow, blue, and white, showed a similar effect on the performance of the poultry as well as the carcass yield (Santana et al., 2014). However, Leigh et al. (2017) found no significant differences in carcass yield, fat %, pectoralis major, total pectoralis, thigh, wing, or leg as % of BW when Cobb broiler chicks were exposed to different white, green, blue, and red LED colors. Moreover, Kumar et al. (2017) reported that white, green, and blue LED colors had no significant effects on carcass yields and cuts and meat quality criteria such as pH, water holding capacity, and shear force, suggesting the use of these LED colors instead of incandescent light without affecting the carcass traits of broilers. These results are in agreement with those of Bennato et al. (2021), who reported that LED light did not affect carcass yield and quality properties of breast meat such as WHC, cooking loss, lightness, fat %, fatty acids profile, and volatile profile of cooked meat. Additionally, Hassan et al. (2016) examined the impacts of light color on meat quality properties. They found that light color had no significant effects on properties such as cooking loss, drip loss, shear force, fatty acids profile, and meat color.

In contrast, Cao et al. (2008) observed that the cross-sectional area and density of myofibers changed among different light color groups, with broilers exposed to blue LED light having a larger myofiber area than those exposed to white, red, or green light. These results suggest that light can influence myofiber growth in the broiler's skeletal muscle, affecting water holding capacity. Furthermore, Hassan et al. (2016) noticed that monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) percentages were numerically increased with increasing light wavelength. In another study, Kim et al. (2013) found that red light LED increased the content of MUFA, saturated fatty acids (SFA), and the SFA/PUFA ratio while decreasing the concentration of PUFA, n-3 fatty acid, and n-6 fatty acid. Hassan et al. (2014 a) also examined different light colors (red, yellow, green, blue, and combinations of red/yellow, yellow/green, and green/blue) on Ross broiler meat and found that blue and green/blue lights increased meat pH, decreased shear force, and L*. Conclusively, the abovementioned results recommended that LED light can be used as an economic savings for poultry farming without significant alterations to the production parameters or the quality of the broiler meat.

Monochromatic light and broiler physiological response

Blood hematological and biochemical indices

Blood biochemical parameters can serve as physiological indicators for assessing the animal health status as several factors affect the physiological blood variables, including nutrition, environmental elements, species, age, sex, season, and physiological condition (Abd El-Moneim et al., 2019; Abd El-Hack et al., 2020; Abdel-Moneim et al., 2020, 2021; Abo Ghanima et al., 2020 a, 2020 b; Ghanima et al., 2021; Saleh et al., 2021). By adjusting specific environmental elements in the poultry housing, such as light color and lighting settings, the immune function can be improved in order to elicit a more robust response against infections, which impair the production and welfare of poultry (Firouzi et al., 2014; Xie et al., 2008; Zhang et al., 2014). The light color influences the stress response, influencing blood hematological and biochemical parameters (Bedanova et al., 2007; Erol and Cantekin, 2007).

Previous research has shown contradictory results on the effect of different LED light colors on hematological parameters of broiler chickens. On the one hand, Abdelazeem (2019) reported no significant variations in RBCs, WBCs, Hb, PCV, and lymphocyte % when broiler chickens were exposed to white, blue, or green LED light. Furthermore, Kim et al. (2013) and Hassan et al. (2013) revealed that WBC count and H/L ratio were not significantly affected by different LED lighting colors (white, blue, red, green, and yellow) in 35-day-old broiler chickens. On the other hand, Tabeekh (2016) showed a significant effect of light color on RBC and WBC counts, hemoglobin concentration, and PCV, particularly under blue-green light treatment. The same findings were reported by Mohamed et al. (2020), who showed significant elevation in RBCs, PCV, and Hb values when Cobb Avian-48 broiler chicks were exposed to greenish blue, blue, green, and warm light. Additionally, Mohamed et al. (2017) found that Avian-48 broilers exposed to blue and green LED had higher Hb, RBCs, PCV, TLC, and lymphocytes and lower H/L ratio compared to white LED light color. These results are in agreement with those of Mohamed et al. (2014) and Oke et al. (2021). Overall, the studies conducted so far on this topic have provided inconsistent results and more research is needed to confirm the effect of different LED light colors on the hematological parameters of broiler chickens.

The effect of different LED light colors on blood biochemical indices has been reported. Abdelazeem (2019) observed that light colors positively affect liver status, whereas ALT and AST significantly decreased for birds when exposed to LED blue color. However, Firouzi et al. (2014) found that exposing broilers to yellow light resulted in a substantial rise in total serum protein, whereas blue light resulted in a negligible decrease in serum glucose compared to birds exposed to other colors. Similarly, Mohamed et al. (2020) found that total protein, albumin, AST, and ALT values were higher when Cobb Avian-48 broiler chicks were exposed to greenish blue, blue, green, and warm light, respectively. Also, Mohamed et al. (2017) found that exposing broiler chickens to blue and green LED lights increased total protein, albumin, and globulin and lowered AST and ALT levels in their serum compared to those exposed to white LED color. Furthermore, Hassan et al. (2013, 2016) discovered that blue light color lowered blood glucose, total protein, triglycerides, total cholesterol, HDL, and LDL levels.

Light color also can have an impact on broilers' hormones. El-Husseiny et al. (2000) found that green light had a positive effect on concentrations of triiodothyronine (T_3) and thyroxine (T_4) in broilers' plasma. Rozenboim et al. (2004) observed that at 35 days of age, birds exposed to white, green, and blue/green light had higher levels of T_3 than those exposed to blue light. The authors also noticed that T_4 levels were higher in blue/green light-treated chicks than in blue light-treated ones. Abdelazeem (2019) also found that light color significantly affects hormone concentrations, with levels of T_3, T_4, melatonin, and corticosterone decreasing when chicks were exposed to blue LED light, possibly due to lower activity. Additionally, others reported that blue or green light is better for broilers than red or white light as it keeps the birds calmer and reduces stress (Jiang et al., 2016; Senaratna et al., 2016). Contrarily, Soliman and Hassan (2019) found that blue LED light reduced T_3 and T_4 when Ross broiler chicks were exposed to 4 intermittent lightings using different colors (red, blue, and white) LED lights, respectively.

Previous research has shown that blue and green lighting can reduce oxidative stress and enhance the immune response of broiler chickens. Abdo et al. (2017) found that blue light reduced the level of MDA, a marker of oxidative stress, and increased the activity of antioxidant enzymes SOD and CAT in chickens exposed to different light colors during heat stress. Seyidoğlu et al. (2020) reported that exposing Ross 308 broiler chicks to red light increased MDA levels; however, green light increased all antioxidant parameters more than blue light. Furthermore, a study conducted by Seo et al. (2015) found that using a short wavelength of light, such as green, blue, and bright blue, can improve the immune function of broiler chickens. This is because blue and green light wavelengths enhance the cellular immune response and relieve stress by decreasing circulating interleukin-1β. Moreover, chickens grown under green light have been found to have high levels of Newcastle disease antibodies and lower levels of maternal antibodies (Xie et al., 2008). Additionally, Hassan et al. (2013) revealed that at 35 days, exposing broilers to blue-green light increased IgG and IgA. This revealed that red light might be a stressor for broilers, while green light may benefit growth, oxidant-antioxidant balance, and homeostasis.

Monochromatic light and broiler behavior

Studies in poultry behavior have demonstrated the correlation between animal welfare and behavior, mak-

ing it one of the most potent indicators of welfare known to scientists. The duration of light waves received by birds has been found to influence poultry behavior heavily (Maddocks et al., 2001). Research has concluded that exposure to blue LED light can improve welfare and mitigate stress in broiler chicks (Mohamed et al., 2014). Additionally, rearing broiler chicks under blue and green LED light has been found to improve growth performance, physiological response, and reduce fear and stress responses (Balabel et al., 2017; Mohamed et al., 2017). LED blue and green light has also been shown to lead to more comfort behaviors, indicating better welfare in housing conditions (Lucena et al., 2020). Franco et al. (2022 b) findings also unveiled that light color wielded an influence on behavior, particularly notable at the 33- to 34-day mark. During this period, birds subjected to white light displayed greater activity, while those exposed to blue light allocated more time to rest. The cycling between green and blue light and combining of both colors with white light can lead to better comfort behaviors and higher growth performance (Oke et al., 2021).

Studies have shown that exposure to blue and green LED light for 23 hours a day can enhance broiler chicken development performance and welfare by decreasing stress and fright reactions (Mohamed et al., 2017). The best results in terms of plumage quality and foot and toe health in Fayoumi chickens were obtained through exposure to blue light among different colors of light (Hesham et al., 2018). Ross broiler chicks raised under white LED light that includes UVA wavelengths were found to have better gait scores and feather conditions than the control group (James et al., 2018). These findings suggest that incorporating UVA wavelengths in LED lights for broiler chickens could lead to positive impacts on bird welfare. Conversely, red light has been found to promote aggressive behavior in chickens, such as feather pecking and cannibalism (Rozenboim et al., 2004, 1999; Sultana et al., 2013; Xie et al., 2008). On the other hand, blue light has been observed to reduce activity in turkeys (Levenick and Leighton Jr, 1988), and red light has been shown to reduce cannibalism in chickens because birds were unable to perceive the blood on injured birds (North and Bell, 1990). Blue light may help reduce stress by lowering serum interleukin-1 levels (Xie et al., 2008). The same findings were reported by Franco et al. (2022 b), who unveiled that birds reared under blue light exhibited reduced fear levels, as evidenced by a shorter latency to rise during the tonic immobility test and a decreased percentage of birds moving in response to the presence of an observer passing by. The authors also revealed that light color induced alterations in stress levels, as indicated by a lower H:L ratio observed in broilers raised under blue light compared to those under white light. Green light was found to be more comfortable for chickens compared to other lights, due to the increasing frequency of preening, dust bathing, and drinking, while blue light exposure increased litter scratching (Hesham et al., 2018; Senaratna et al., 2012). Birds raised in red light environments were more active and showed increased aggression, while those raised in blue and green light were more calm and relaxed (Abdelazeem, 2019; Abu-Tabeekh and Shawkat, 2015). In an open-field test, blue and green light-raised birds showed lower fear and increased exploration (Mohamed et al., 2017). Blue light was found to enhance behaviors such as sleeping, sitting, and idling (Hesham et al., 2018). These results suggest that the color of light has a significant impact on the brain response and behavior of chickens, influencing their fear behavior (Dharmaretnam and Rogers, 2005).

Lighting can impact broiler chicken welfare and development, with specific colors and intensity having different effects on various aspects such as behavior, lameness, and skeletal abnormalities. According to Abdelazeem (2019), blue light has the best effect on tibia bone characteristics (weight, length, width, ash %, calcium %, phosphorous %, and breaking strength) and reduces the length of tonic immobility. However, Franco et al. (2022 c) noticed no effect of light color (blue, green, or white) on birds' mobility and footpad dermatitis. On the other hand, red and red-yellow light increases the duration of tonic immobility. Hassan et al. (2016) found that specific light wavelengths can impact tibial bone mineral density (BMD) and that red and red-blue-green light might improve BMD due to increased physical activity, promoting bone tissue growth. These findings are consistent with previous studies by Bizeray et al. (2000) and Sultana et al. (2013).

Light colors play a crucial role in broiler chicken welfare, affecting their eating, drinking, and sleeping behaviors, as well as their stress levels and mobility. When broiler chickens were exposed to blue and green light, they showed the highest eating and drinking frequencies (El-Husseiny et al., 2000). On the other hand, red and incandescent light increased feed intake, while yellow light had the least effect (Jiang et al., 2012). A study by Balabel et al. (2017) found that cycling between green and blue light increased rest and sleep time in Cobb chicks, while white light decreased it. Light colors had no effect on preening and wing flapping, but white light increased ground pecking and tonic immobility behaviors. Lucena et al. (2020) found that blue/green light colors improved comfort behaviors and reduced aggressive behavior in Cobb broiler birds, while white light increased discomfort. A study by Mohamed et al. (2020) found that blue, green, and green/blue light improved tonic immobility, mobility, and comfort behaviors in Avian-48 broiler chicks, while white light had the worst effect. Combining green and blue light was found to improve broiler development and boost chicken welfare and performance (Oke et al., 2021). Green light was found to have a natural effect on male Cobb broiler behavior, increasing their attendance at the bird feeder and decreasing idleness (José Paixão et al., 2022). Briefly, the use of LED light, particularly blue and green, in broiler houses holds significant potential for improving the welfare of broiler chickens.

Conclusion and future perspective

Studying the impact of light wavelength on the growth and welfare of broiler chickens is an intricate and multifaceted topic. This review article has highlighted light wavelength's profound significance for various physiological processes, welfare, and overall health of broiler chickens. Research findings reveal that blue and green light exhibit the potential to enhance body weight, whereas red light may intensify aggressiveness and negatively affect performance. The strategic incorporation of mixed light sources and periods of darkness is pivotal for promoting bird health and productivity. Furthermore, studies have demonstrated that the use of specific wavelengths can yield positive environmental outcomes, such as reducing energy consumption. Moreover, LED lighting technology becomes the preferred choice for broiler producers due to its precise control of the spectral composition of light, energy efficiency, and long lifespan.

Emerging light technologies hold promising future perspectives in broiler production, including circadian and smart lighting. Circadian lighting, designed to mimic the natural light cycle, demonstrates remarkable potential in enhancing broiler health and welfare. By fostering growth, alleviating stress, and tackling behavioral concerns such as feather pecking and cannibalism, it operates akin to light therapy. On the flip side, smart lighting, characterized by its remote controllability, introduces a new dimension of adaptability. Tailoring lighting programs according to variables such as time, weather, and chicken behavior not only enhances efficiency but also contributes to overall well-being.

However, further research is indispensable to integrate these emerging light technologies into broiler production seamlessly. A comprehensive understanding of the effects of light wavelength on the welfare and sustainability of broiler chickens is also needed to support the development of more humane and sustainable farming practices. As consumers' awareness regarding the environmental impact of food production escalates, the use of more energy-efficient lighting techniques could gain increasing significance, paving the way for sustainable and ethical poultry production.

Conflict of interest

All authors declare that they have no conflicts of interest that could inappropriately influence this manuscript.

Data availability statement

The Review Manuscript has been made by collecting and analyzing the data of research manuscripts from Open Access sources.

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References

Abd El-Hack M.E., El-Saadony M.T., Shafi M.E., Qattan S.Y., Batiha G.E., Khafaga A.F., Abdel-Moneim A.M.E., Alagawany M. (2020). Probiotics in poultry feed: A comprehensive review. J. Anim. Physiol. Anim. Nutr., 104: 1835–1850.

Abd El-Moneim A.E., Sabic E.M., Abu-Taleb A.M. (2019). Influence of dietary supplementation of irradiated or non-irradiated olive pulp on biochemical profile, antioxidant status and immune response of Japanese quails. Biol. Rhythm Res., 53: 519–534.

Abd El Naby W.S.H., Basha H.A., Ibrahim S.E., Abo-Samaha M.I. (2021). Effects of red and blue light during the incubation of turkey eggs on hatchability performance and expression pattern of some myogenic regulatory genes. J. World's Poult. Res., 11: 129–135.

Abdel-Moneim A.-M.E., Shehata A.M., Alzahrani S.O., Shafi M.E., Mesalam N.M., Taha A.E., Swelum A.A., Arif M., Fayyaz M., Abd El-Hack M.E. (2020). The role of polyphenols in poultry nutrition. J. Anim. Physiol. Anim. Nutr., 104: 1851–1866.

Abdel-Moneim A.-M.E., Shehata A.M., Khidr R.E., Paswan V.K., Ibrahim N.S., El-Ghoul A.A., Aldhumri S.A., Gabr S.A., Mesalam N.M., Elbaz A.M. (2021). Nutritional manipulation to combat heat stress in poultry – A comprehensive review. J. Therm. Biol., 102915.

Abdelazeem A.F. (2019). Productive and physiological response of broiler chickens exposed to different colored light-emitting diode and reared under different stocking densities. Egypt. Poult. Sci. J., 38: 1243–1264.

Abdo S.E., El-Kassas S., El-Nahas A.F., Mahmoud S. (2017). Modulatory effect of monochromatic blue light on heat stress response in commercial broilers. Oxid. Med. Cell. Longev., 2017: 1351945.

Abdulateef S.M., Al-Bayar M., Majid A., Shawkat S., Tatar A., Al-Ani M. (2021). Effect of exposure to different light colors on embryonic development and neurophysiological traits in the chick embryo. Vet. World, 14: 1284.

Abo Ghanima M.M., Abd El-Hack M.E., Othman S.I., Taha A.E., Allam A.A., Abdel-Moneim A.-M.E. (2020 a). Impact of different rearing systems on growth, carcass traits, oxidative stress biomarkers, and humoral immunity of broilers exposed to heat stress. Poultry Sci., 99: 3070–3078.

Abo Ghanima M.M., Bin-Jumah M., Abdel-Moneim A.-M.E., Khafaga A.F., Abd El-Hack M.E., Allam A.A., El-Kasrawy N.I. (2020 b). Impacts of strain variation on response to heat stress and boldo extract supplementation to broiler chickens. Animals, 10: 24.

Abu-Tabeekh M., Shawkat T.F. (2015). Effect of light color and stocking density on some behavioral traits of broilers and layers. MRJASSS3, 9: 122–130.

Akyüz H.Ç., Onbaşilar E. (2018). Light wavelength on different poultry species. Worlds Poult. Sci. J., 74: 79–88.

Archer G. (2017). Exposing broiler eggs to green, red and white light during incubation. Animal, 11: 1203–1209.

Archer G.S., Shivaprasad H., Mench J. (2009). Effect of providing light during incubation on the health, productivity, and behavior of broiler chickens. Poultry Sci., 88: 29–37.

Atapattu N., Wickramasinghe K. (2007). The use of refused tea as litter material for broiler chickens. Poultry Sci., 86: 968–972.

Balabel T., Mohamed R., Saleh M. (2017). Using different light colors as a stress factor on broiler performance in Egypt. Aust. J. Basic and Appl. Sci., 11: 165–170.

Baxter M., Joseph N., Osborne V., Bedecarrats G. (2014). Red light is necessary to activate the reproductive axis in chickens independently of the retina of the eye. Poultry Sci., 93: 1289–1297.

Bedanova I., Voslarova E., Chloupek P., Pistekova V., Suchy P., Blahova J., Dobsikova R., Vecerek V. (2007). Stress in broilers resulting from shackling. Poultry Sci., 86: 1065–1069.

Bennato F., Ianni A., Martino C., Grotta L., Martino G. (2021). Evaluation of chemical composition and meat quality of breast muscle in broilers reared under light-emitting diode. Animals, 11: 1505.

Bizeray D., Leterrier C., Constantin P., Picard M., Faure J. (2000).

Early locomotor behaviour in genetic stocks of chickens with different growth rates. Appl. Anim. Behav. Sci., 68: 231–242.
Cao J., Liu W., Wang Z., Xie D., Jia L., Chen Y. (2008). Green and blue monochromatic lights promote growth and development of broilers via stimulating testosterone secretion and myofiber growth. J. Appl. Poult. Res., 17: 211–218.
Cao J., Wang Z., Dong Y., Zhang Z., Li J., Li F., Chen Y. (2012). Effect of combinations of monochromatic lights on growth and productive performance of broilers. Poultry Sci., 91: 3013–3018.
Cave N. (1990). Effects of feeding level during pullet-layer transition and of pretransition lighting on performance of broiler breeders. Poultry Sci., 69: 1141–1146.
Chang Y.-L., Lu Z.-H. (2013). White organic light-emitting diodes for solid-state lighting. J. Disp. Technol., 9: 459–468.
Classen H. (2003). Barn of the future lighting programs. Ministry of Agriculture and Food, Government of Ontario, Canada.
Classen H.L. (2004). Day length affects performance, health and condemnations in broiler chickens. Proc. 16th Australian Poult. Sci. Symposium, Sydney, New South Wales, Australia, 9–11.02.2004.
Dawson A., King V.M., Bentley G.E., Ball G.F. (2001). Photoperiodic control of seasonality in birds. J. Biol. Rhythms, 16: 365–380.
Dharmaretnam M., Rogers L. (2005). Hemispheric specialization and dual processing in strongly versus weakly lateralized chicks. Behav. Brain Res., 162: 62–70.
Dishon L., Avital-Cohen N., Zaguri S., Bartman J., Heiblum R., Druyan S., Porter T., Gumulka M., Rozenboim I. (2021 a). *In ovo* green light photostimulation during the late incubation stage affects somatotropic axis activity. Poultry Sci., 100: 467–473.
Dishon L., Avital-Cohen N., Zaguri S., Bartman J., Heiblum R., Druyan S., Porter T., Gumułka M., Rozenboim I. (2021 b). The effect of selected *in ovo* green light photostimulation periods on post-hatch broiler growth and somatotropic axis activity. Poultry Sci., 100: 101229.
Drozdova A., Okuliarova M., Zeman M. (2019). The effect of different wavelengths of light during incubation on the development of rhythmic pineal melatonin biosynthesis in chick embryos. Animal, 13: 1635–1640.
Egbuniwe I., Ayo J. (2016). Physiological roles of avian eyes in light perception and their responses to photoperiodicity. Worlds Poult. Sci. J., 72: 605–614.
El-Husseiny O., Hashish S., Arafa S., Madian A. (2000). Response of poultry performance to environmental light colour. Egypt. Poult. Sci. J., 20: 385–402.
El-Sabrout K., Khalil M.H. (2017). Effect of LED lighting on hatchability and chick performance of chicken eggs. Pak. J. Zool., 49.
El-Sabrout K., El-Deek A., Ahmad S., Usman M., Dantas M.R.T., Souza-Junior J.B.F. (2022). Lighting, density, and dietary strategies to improve poultry behavior, health, and production. J. Anim. Behav. Biometeorol., 10: 2212.
Erol H., Cantekin Z. (2007). Influence of intermittent lighting on broiler performance, incidence of tibial dyschondroplasia, tonic immobility, some blood parameters and antibody production. Asian-australas. J. Anim. Sci., 20: 550–555.
Firouzi S., Nazarpak H.H., Habibi H., Jalali S.S., Nabizadeh Y., Rezaee F., Ardali R., Marzban M. (2014). Effects of color lights on performance, immune response and hematological indices of broilers. J. World's Poult. Res, 4: 52–55.
Franco B.R., Shynkaruk T., Crowe T., Fancher B., French N., Gillingham S., Schwean-Lardner K. (2022 a). Does light color during brooding and rearing impact broiler productivity? Poultry Sci., 101: 101937.
Franco B.R., Shynkaruk T., Crowe T., Fancher B., French N., Gillingham S., Schwean-Lardner K. (2022 b). Light color and the commercial broiler: effect on behavior, fear, and stress. Poultry Sci., 101: 102052.
Franco B.R., Shynkaruk T., Crowe T., Fancher B., French N., Gillingham S., Schwean-Lardner K. (2022 c). Light wavelength and its impact on broiler health. Poultry Sci., 101: 102178.
Fritts C., Waldroup P. (2003). Effect of source and level of vitamin D on live performance and bone development in growing broilers. J. Appl. Poult. Res., 12: 45–52.
Fritts C., Waldroup P. (2005). Comparison of cholecalciferol and 25-hydroxycholecalciferol in broiler diets designed to minimize phosphorus excretion. J. Appl. Poult. Res., 14: 156–166.
Ghanima M.M.A., Abd El-Hack M.E., Abougabal M.S., Taha A.E., Tufarelli V., Laudadio V., Naiel M.A. (2021). Growth, carcass traits, immunity and oxidative status of broilers exposed to continuous or intermittent lighting programs. Anim. Biosci., 34: 1243.
Gržinić G., Piotrowicz-Cieślak A., Klimkowicz-Pawlas A., Górny R.L., Ławniczek-Wałczyk A., Piechowicz L., Olkowska E., Potrykus M., Tankiewicz M., Krupka M. (2023). Intensive poultry farming: A review of the impact on the environment and human health. Sci. Total Environ., 858: 160014.
Guevara B., Pech P., Zamora B., Navarrete S., Magaña S. (2015). Performance of broilers reared under monochromatic light emitting diode supplemental lighting. Braz. J. Poult. Sci., 17: 553–558.
Hakan B., Ali A. (2005). Effects of light wavelength on broiler performance. Hayvansal Üretim, 46: 22–32.
Halevy O., Biran I., Rozenboim I. (1998). Various light source treatments affect body and skeletal muscle growth by affecting skeletal muscle satellite cell proliferation in broilers. Comp. Biochem. Physiol., 120: 317–323.
Hassan M.R., Sultana S., Choe H.S., Ryu K.S. (2013). Effect of monochromatic and combined light colour on performance, blood parameters, ovarian morphology and reproductive hormones in laying hens. Ital. J. Anim. Sci., 12: e56.
Hassan M.R., Sultana S., Choe H.S., Ryu K.S. (2014 a). A comparison of monochromatic and mixed LED light color on performance, bone mineral density, meat and blood properties, and immunity of broiler chicks. J. Poult. Sci., 51: 195–201.
Hassan M.R., Sultana S., Choe H.S., Ryu K.S. (2014 b). Effect of combinations of monochromatic LED light color on the performance and behavior of laying hens. J. Poult. Sci., 51: 321–326.
Hassan M.R., Sultana S., Kim S.H., Ryu K. (2016). Effect of monochromatic and combined LED light colours on performance, blood characteristics, meat fatty acid composition and immunity of broiler chicks. Europ. Poultry Sci., 80: 1–17.
Helva I., Aksit M., Yalcin S. (2019). Effects of monochromatic light on growth performance, welfare and hormone levels in broiler chickens. Europ. Poult. Sci., 83.
Hesham M., El Shereen A., Enas S. (2018). Impact of different light colors in behavior, welfare parameters and growth performance of Fayoumi broiler chickens strain. J. Hell. Vet. Med. Soc., 69: 951–958.
Hluchý S., Toman R., Cabaj M., Adamkovičová M. (2012). The effect of white and monochromatic lights on chicken hatching. Scientific Papers: J. Anim. Sci. Biotechnol., 45: 408–410.
Hunt D.M., Carvalho L.S., Cowing J.A., Davies W.L. (2009). Evolution and spectral tuning of visual pigments in birds and mammals. Philos. Trans. R. Soc. Lond. B Biol. Sci., 364: 2941–2955.
Iribarren R., Rozema J.J., Schaeffel F., Morgan I.G. (2014). Calculation of crystalline lens power in chickens with a customized version of Bennett's equation. Vis. Res., 96: 33–38.
James C., Asher L., Herborn K., Wiseman J. (2018). The effect of supplementary ultraviolet wavelengths on broiler chicken welfare indicators. Appl. Anim. Behav. Sci., 209: 55–64.
Jiang J., Pan J., Wang Y., Ye Z., Ying Y. (2012). Effect of light color on growth and waste emission of broilers. Proc. IX Int. Livestock Environ. Symp. (ILES IX).
Jiang N., Wang Z., Cao J., Dong Y., Chen Y. (2016). Role of monochromatic light on daily variation of clock gene expression in the pineal gland of chick. J. Photochem. Photobiol. B Biol., 164: 57–64.
Jiao Y., Lau T., Hatzikirou H., Meyer-Hermann M., Corbo J.C., Torquato S. (2014). Avian photoreceptor patterns represent a disordered hyperuniform solution to a multiscale packing problem. Phys. Rev. E., 89: 022721.
José Paixão S., Mendes A.S., Possenti M.A., Sikorski R.R., do Vale M.M., de Souza C., Guimarães B.E., de Moura D.J., de Alencar Nääs I., Nunes I.B. (2022). Broiler behavior differs from males to females when under different light wavelengths. Trop. Anim. Health Prod., 54: 1–9.
Kalia S., K Bharti V., Gogoi D., Giri A., Kumar B. (2017). Studies on the growth performance of different broiler strains at high altitude

and evaluation of probiotic effect on their survivability. Sci. Rep., 7: 1–8.
Karim E.-S. (2017). Effect of LED lighting during incubation of Fayoumi eggs on hatchability and chick performance. Kafkas Üniversitesi Veteriner Fakültesi Dergisi, 23.
Khosravinia H. (2007). Preference of broiler chicks for color of lighting and feed. J. Poult. Sci., 44: 213–219.
Kim M., Parvin R., Mushtaq M., Hwangbo J., Kim J., Na J., Kim D., Kang H., Kim C., Cho K. (2013). Growth performance and hematological traits of broiler chickens reared under assorted monochromatic light sources. Poultry Sci., 92: 1461–1466.
Kram Y.A., Mantey S., Corbo J.C. (2010). Avian cone photoreceptors tile the retina as five independent, self-organizing mosaics. PLoS One, 5: e8992.
Kristensen H.H., Prescott N.B., Perry G.C., Ladewig J., Ersbøll A.K., Overvad K.C., Wathes C.M. (2007). The behaviour of broiler chickens in different light sources and illuminances. Appl. Anim. Behav. Sci., 103: 75–89.
Kuenzel W.J., Kang S.W., Zhou Z.J. (2015). Exploring avian deep-brain photoreceptors and their role in activating the neuroendocrine regulation of gonadal development. Poultry Sci., 94: 786–798.
Kumar S., Gupta R.K., Sharma A., Singh Y., Mehta N., Kashyap N. (2017). Performance and carcass characteristics of broiler chickens reared under light emitting diodes (LEDs) light vis-a-vis incandescent light supplemental lighting programme. J. Anim. Res., 7: 1157–1163.
Lan X., Li D., Wang V., Zhao X., Liu Y., Zhu Q. (2013). Effect of monochromatic light on the crown performance of chickens. Indian J. Anim. Res., 47: 175–177.
Leigh M., McFadden T., Schumacher L., Firman J. (2017). Efficacy of various wavelengths of monochromatic light emitting diode illumination on growth and performance of broiler chickens. Int. J. Poult. Sci., 16: 475–480.
Levenick C., Leighton Jr A. (1988). Effects of photoperiod and filtered light on growth, reproduction, and mating behavior of turkeys: 1. Growth performance of two lines of males and females. Poultry Sci., 67: 1505–1513.
Lewis P. (2010). Lighting, ventilation and temperature. Brit. Poult. Sci., 51: 35–43.
Lewis P., Gous R. (2009). Responses of poultry to ultraviolet radiation. Worlds Poult. Sci. J., 65: 499–510.
Lewis P., Morris T. (1998). Responses of domestic poultry to various light sources. Worlds Poult. Sci. J., 54: 7–25.
Lewis P., Morris T. (2000). Poultry and coloured light. Worlds Poult. Sci. J., 56: 189–207.
Lewis P.D., Morris T.R. (2006). Poultry lighting: the theory and practice. Northcot.
Li X., Rathgeber B., McLean N., MacIsaac J. (2021). Providing colored photoperiodic light stimulation during incubation: 1. Effects on embryo development and hatching performance in broiler hatching eggs. Poultry Sci., 100: 101336.
Liu W., Chen Y., Wang Z., Dong Y., Cao J., Xie D., Jia L. (2008). Effect of monochromatic light on the muscle growth and muscle fiber development and testosterone secretion in broilers. Acta Vet. Zoot. Sin., 39: 1759–1764.
Liu W., Wang Z., Chen Y. (2010). Effects of monochromatic light on developmental changes in satellite cell population of pectoral muscle in broilers during early posthatch period. Anat. Rec.: Adv. Integr. Anat. Evol. Biol., 293: 1315–1324.
Lucena A.C., Pandorfi H., Almeida G.L., Guiselini C., Araújo J.E., Rodrigues T.P.d.S. (2020). Behavior of broilers subjected to different light spectra and illuminances. Rev. Bras. Eng. Agr. Amb., 24: 415–421.
Maddocks S.A., Cuthill I.C., Goldsmith A.R., Sherwin C.M. (2001). Behavioural and physiological effects of absence of ultraviolet wavelengths for domestic chicks. Anim. Behav., 62: 1013–1019.
Mendes A.S., Paixão S.J., Restelatto R., Morello G.M., de Moura D.J., Possenti J.C. (2013). Performance and preference of broiler chickens exposed to different lighting sources. J. Appl. Poult. Res., 22: 62–70.
Mills E., Jacobson A. (2011). From carbon to light: a new framework for estimating greenhouse gas emissions reductions from replacing fuel-based lighting with LED systems. Energ. Effic., 4: 523–546.
Mo Q., Kulyar M.F.-e.-A., Quan C., Ding Y., Zhang Y., Zhang L., Pan H., Li J. (2023). Thiram-induced hyperglycemia causes tibial dyschondroplasia by triggering aberrant ECM remodeling via the gut-pancreas axis in broiler chickens. J. Hazard. Mater., 444: 130368.
Mohamed R., Eltholth M., El-Saidy N. (2014). Rearing broiler chickens under monochromatic blue light improve performance and reduce fear and stress during pre-slaughter handling and transportation. Biotechnol. Anim. Husb., 30: 457–471.
Mohamed R., Abou-Elnaga A., Ghazy E., Mohammed H., Shukry M., Farrag F., Mohammed G., Bahattab O. (2020). Effect of different monochromatic LED light colour and intensity on growth performance, physiological response and fear reactions in broiler chicken. Ital. J. Anim. Sci., 19: 1099–1107.
Mohamed R.A., El-Kholya S.Z., Shukry M., El-Kassas S., El Saidy N.R. (2017). Manipulation of broiler growth performance, physiological and fear responses using three monochromatic LED lights. Alex. J. Vet. Sci., 53.
Montiani-Ferreira F., Li T., Kiupel M., Howland H., Hocking P., Curtis R., Petersen-Jones S. (2003). Clinical features of the retinopathy, globe enlarged (rge) chick phenotype. Vis. Res., 43: 2009–2018.
Mosa R.K., Abbas R.J., Tabeekh M.A.A. (2014). The effect of color light and stocking density on some traits of broiler carcasses. MRVSA, 3: 24–35.
North M.O., Bell D.D. (1990). Commercial chicken production manual. Van Nostrand Reinhold.
Nuboer J. (1993). Visual ecology in poultry houses. Utrecht Biophysics Research Institute, Division: Comparative Physiology, Utrecht University.
Oke O., Oni A., Adebambo P., Oso O., Adeoye M., Lawal T., Afolayan T., Ogunbajo O., Ojelade D., Bakre O. (2021). Evaluation of light colour manipulation on physiological response and growth performance of broiler chickens. Trop. Anim. Health Prod., 53: 1–9.
Olanrewaju H., Purswell J., Collier S., Branton S. (2011). Effect of varying light intensity on growth performance and carcass characteristics of broiler chickens grown to heavy weights. Int. J. Poult. Sci., 10: 921–926.
Olanrewaju H., Miller W., Maslin W., Collier S., Purswell J., Branton S. (2018). Influence of light sources and photoperiod on growth performance, carcass characteristics, and health indices of broilers grown to heavy weights. Poultry Sci., 97: 1109–1116.
Olkowski A., Classen H. (1998). High incidence of cardiac arrhythmias in broiler chickens. J. Vet. Med. Series A, 45: 83–91.
Ozkan M., Simsek U.G. (2022). The effect of light/dark cycles on performance and welfare in broiler. Ann. Anim. Sci., 22: 795–802.
Parvin R., Mushtaq M., Kim M., Choi H. (2014). Light emitting diode (LED) as a source of monochromatic light: a novel lighting approach for behaviour, physiology and welfare of poultry. Worlds Poult. Sci. J., 70: 543–556.
Prescott N., Wathes C.M., Jarvis J. (2003). Light, vision and the welfare of poultry. Anim. Welf., 12: 269–288.
Rana M.S., Campbell D.L. (2021). Application of ultraviolet light for poultry production: a review of impacts on behavior, physiology, and production. Front. Anim. Sci., 2: 699262.
Remonato Franco B., Leis M.L., Wong M., Shynkaruk T., Crowe T., Fancher B., French N., Gillingham S., Schwean-Lardner K. (2022). Light color and the commercial broiler: effect on ocular health and visual acuity. Front. Physiol., 13: 413.
Rogers A.G., Pritchett E.M., Alphin R.L., Brannick E.M., Benson E.R. (2015). I. Evaluation of the impact of alternative light technology on male broiler chicken growth, feed conversion, and allometric characteristics. Poultry Sci., 94: 408–414.
Rozenboim I., Biran I., Uni Z., Robinzon B., Halevy O. (1999). The effect of monochromatic light on broiler growth and development. Poultry Sci., 78: 135–138.
Rozenboim I., Biran I., Chaiseha Y., Yahav S., Rosenstrauch A., Sklan D., Halevy O. (2004). The effect of a green and blue monochromatic light combination on broiler growth and development. Poultry Sci., 83: 842–845.

Rucker F. (2019). Monochromatic and white light and the regulation of eye growth. Exper. Eye Res., 184: 172–182.
Saleh A.A., Shukry M., Farrag F., Soliman M.M., Abdel-Moneim A.-M.E. (2021). Effect of feeding wet feed or wet feed fermented by *Bacillus licheniformis* on growth performance, histopathology and growth and lipid metabolism marker genes in broiler chickens. Animals, 11: 83.
Santana M.R.d., Garcia R.G., Naas I.d.A., Paz I.C., Caldara F.R., Barreto B. (2014). Light emitting diode (LED) use in artificial lighting for broiler chicken production. Engenharia Agrícola, 34: 422–427.
Schachar R.A. (2004). Qualitative effect of zonular tension on freshly extracted intact human crystalline lenses: implications for the mechanism of accommodation. Invest. Ophthalmol. Vis. Sci., 45: 2691–2695.
Seifert M., Baden T., Osorio D. (2020). The retinal basis of vision in chicken. Semin. Cell Dev. Biol., 106: 106–115.
Senaratna D., Samarakone T., Atapattu N., Nayanasiri H. (2008). Effect of the colour of light on growth performance, behaviour and bone parameters of broiler chicken. Trop. Agri. Res., 20: 185–195.
Senaratna D., Samarakone T., Madusanka A., Gunawardane W. (2012). Performance, behaviour and welfare aspects of broilers as affected by different colours of artificial light. Trop. Agri. Res. Exten., 14.
Senaratna D., Samarakone T., Gunawardena W. (2016). Red color light at different intensities affects the performance, behavioral activities and welfare of broilers. Asian-australas. J. Anim. Sci., 29: 1052.
Seo H.-S., Kang M., Yoon R.-H., Roh J.-H., Wei B., Ryu K.S., Cha S.-Y., Jang H.-K. (2015). Effects of various LED light colors on growth and immune response in broilers. J. Poult. Sci., 53: 76–81.
Seyidoğlu N., Belenli D., Merhan O., Bozukluhan K. (2020). The effects of different monochromatic colors on oxidant antioxidant balance in broilers. J. Res. Vet. Med., 39: 21–25.
Shafey T., Al-Mohsen T. (2002). Embryonic growth, hatching time and hatchability performance of meat breeder eggs incubated under continuous green light. Asian-Australas. J. Anim. Sci., 15: 1702–1707.
Sissine F. (2007). Energy Independence and Security Act of 2007: a summary of major provisions.
Soliman E.S., Hassan R.A. (2019). Impact of lighting color and duration on productive performance and Newcastle disease vaccination efficiency in broiler chickens. Vet. World, 12: 1052.
Soliman F.N., El-Sabrout K. (2020). Light wavelengths/colors: Future prospects for broiler behavior and production. J. Vet. Behav., 36: 34–39.
Sultana S., Hassan M.R., Choe H.S., Ryu K.S. (2013). The effect of monochromatic and mixed LED light colour on the behaviour and fear responses of broiler chicken. Avian Biol. Res., 6: 207–214.
Tabeekh M. (2016). An investigation on the effect of light color and stocking density on some blood parameters of broilers and layers. Donnish J. Agri. Res., 3: 8–12.
Vasdal G., Kittelsen K.E., Tahamtani F., Nilsson D.-E. (2022). Description of light environment in broiler breeder houses with different light sources – and how it differs from natural forest light. Animals, 12: 3408.
Wabeck C., Skoglund W. (1974). Influence of radiant energy from fluorescent light sources on growth, mortality, and feed conversion of broilers. Poultry Sci., 53: 2055–2059.
Wang P., Sun Y., Fan J., Zong Y., Li Y., Shi L., Isa A.M., Wang Y., Ni A., Ge P. (2020). Effects of monochromatic green light stimulation during embryogenesis on hatching and posthatch performance of four strains of layer breeder. Poultry Sci., 99: 5501–5508.
Wang P., Sun Y., Li Y., Fan J., Zong Y., Isa A.M., Shi L., Wang Y., Ni A., Ge P. (2021). Monochromatic green light stimulation during incubation shortened the hatching time via pineal function in White Leghorn eggs. J. Anim. Sci. Biotechnol., 12: 1–10.
Wei Y., Zheng W., Li B., Tong Q., Shi H. (2020). Effects of a two-phase mixed color lighting program using light-emitting diode lights on layer chickens during brooding and rearing periods. Poultry Sci., 99: 4695–4703.
Wilson M., Lindstrom S.H. (2011). What the bird's brain tells the bird's eye: the function of descending input to the avian retina. Vis. Neurosci., 28: 337–350.
Wu Y., Huang J., Quan S., Yang Y. (2022). Light regimen on health and growth of broilers: an update review. Poultry Sci., 101: 101545.
Xie D., Wang Z., Dong Y., Cao J., Wang J., Chen J., Chen Y. (2008). Effects of monochromatic light on immune response of broilers. Poultry Sci., 87: 1535–1539.
Xie D., Li J., Wang Z., Cao J., Li T., Chen J., Chen Y. (2011). Effects of monochromatic light on mucosal mechanical and immunological barriers in the small intestine of broilers. Poultry Sci., 90: 2697–2704.
Yang Y., Jiang J., Wang Y., Liu K., Yu Y., Pan J., Ying Y. (2016 a). Light-emitting diode spectral sensitivity relationship with growth, feed intake, meat, and manure characteristics in broilers. Trans. ASABE, 59: 1361–1370.
Yang Y., Yu Y., Pan J., Ying Y., Zhou H. (2016 b). A new method to manipulate broiler chicken growth and metabolism: Response to mixed LED light system. Sci. Rep., 6: 1–10.
Yarger J., Saunders C., McNaughton J., Quarles C., Hollis B., Gray R. (1995). Comparison of dietary 25-hydroxycholecalciferol and cholecalciferol in broiler chickens. Poultry Sci., 74: 1159–1167.
Zahoor M.S., Ahmad S., Usman M., Dawood M., El-Sabrout K., Hashmi S.G.M.D., Khan E.U., Hussain M., Maqsood M.A., Latif H.R.A. (2022). Effects of mirror and coloured balls as environmental enrichment tools on performance, welfare and meat quality traits of commercial broiler. Trop. Anim. Health Prod., 54: 151.
Zhang L., Zhang H., Qiao X., Yue H., Wu S., Yao J., Qi G. (2012). Effect of monochromatic light stimuli during embryogenesis on muscular growth, chemical composition, and meat quality of breast muscle in male broilers. Poultry Sci., 91: 1026–1031.
Zhang L., Zhu X., Wang X., Li J., Gao F., Zhou G. (2016). Green light-emitting diodes light stimuli during incubation enhances posthatch growth without disrupting normal eye development of broiler embryos and hatchlings. Asian-Australas. J. Anim. Sci., 29: 1562.
Zhang Z., Cao J., Wang Z., Dong Y., Chen Y. (2014). Effect of a combination of green and blue monochromatic light on broiler immune response. J. Photochem. Photobiol. B Biol., 138: 118–123.

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