

Effect of In-Ovo and Post-Hatch Photo Stimulation on Growth Performance and Survivability of Broiler Chickens

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SUMMARY

This study evaluated the effects of *in-ovo* and post-hatch photo stimulation on the growth performance and survivability of broiler chickens. A total of 800 fertile eggs were incubated under three light treatments: green light (GL, 560 nm), blue light (BL, 480 nm), and dark conditions (DL, control). Eggs were exposed to monochromatic light generated by LED lamps in 15-minute intervals, with standard incubation conditions of 37.8°C and 60% relative humidity. Upon hatching, chicks were assigned to three treatment groups: continuous photo stimulation, early post-hatch photo stimulation, and *in ovo* photo stimulation effect after hatching, using Green Light (GL), Blue Light (BL), and White light (WL) control to evaluate the effects of light exposure on post-hatch growth and survivability over six weeks rearing period. Results demonstrated significant improvements in hatching performance and growth parameters under GL and BL treatments. GL-treated eggs produced the heaviest hatchlings (37.49 ± 0.19 g), and BL-treated birds achieved the highest final body weights under continuous photo stimulation (2278.40 ± 36.64 g) and *in ovo* photo stimulation (2409.35 ± 38.32 g). Compared to the dark control, feed conversion ratios (FCR) were low under BL (1.50 ± 0.02), followed by GL (1.63 ± 0.002). Survivability was consistently higher in GL and BL treatments, with BL showing the lowest mortality rates. These findings indicate that photo stimulation, particularly with blue and green light, significantly enhances broiler growth performance, feed efficiency, and survivability, offering a sustainable approach to improving poultry production in tropical environments.

Keywords: Broiler chickens, Photo stimulation, Monochromatic Light, Feed Conversion Ratio, Growth performance, Survivability.

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INTRODUCTION

Poultry production is a vital component of global animal agriculture, providing a high-quality and affordable protein source essential for food security (FAO, 2019). However, in tropical regions, broiler production is increasingly challenged by environmental stressors, particularly heat stress, which is worsened by climate change. Heat stress impairs physiological homeostasis in broiler chickens, leading to reduced feed intake (FI), compromised nutrient absorption and overall declines in growth performance and survivability (Ranjan *et al.*, 2019). As broilers struggle to dissipate excess heat in high-temperature

environments, their metabolic efficiency declines, resulting in poor feed conversion ratio (FCR), lower body weight (BW) gain, and increased mortality rates. Nawaz *et al.* (2021).

Heat stress poses a significant challenge to broiler production, particularly in regions where environmental conditions cannot be easily controlled (Nawab *et al.*, 2018). To mitigate the effects of heat stress, novel strategies are required to optimize broiler performance, particularly in regions where environmental conditions cannot be easily controlled. One promising approach to mitigate the

adverse effects of heat stress is photo stimulation, which involves the controlled exposure of broilers to specific wavelengths of light (Alaqil *et al.*, 2022). Earlier studies have demonstrated that exposure to monochromatic light can positively influence embryonic development and enhance post-hatch growth performance in poultry (Rozenboim *et al.*, 2004; Zhang *et al.*, 2012).

Light is a fundamental regulator of avian development, modulating circadian rhythms, endocrine activity, and metabolic pathways through retinal and hypothalamic photoreceptors (Shafey and Al-Mohsen, 2002; Kuenzel *et al.*, 2015). The physiological responses to photo stimulation are influenced by light source, intensity, photoperiod, and spectral composition (Rozenboim *et al.*, 1999; Shafey and Al-Mohsen, 2002). Photo stimulation during both incubation and the post-hatch period can modulate developmental physiology, potentially enhancing growth performance through photoreceptor-mediated pathways and regulation of the somatotropic axis. Photoreceptor gene expression is initiated early in embryogenesis, reaching full functionality in the later stages of incubation (Wai *et al.*, 2006). Photocues received through the retinal and hypothalamic extraretinal photoreceptors by opsins and chromophore molecules (Shafey and Al-Mohsen, 2002; Rozenboim *et al.*, 2013; Kuenzel *et al.*, 2015) promote a conformational change of the receptors, generating a biochemical signal affecting the release of neurotransmitters to induce a response.

Existing evidence demonstrated that specific light wavelengths, particularly in the green (GL) and blue (BL) spectrum, elevate the expression of growth factors during embryogenesis in the broilers (Halevy *et al.*, 2006a; Al-Musawi *et al.*, 2012) inducing a subtle increase in yolk temperature (1°C) attributed by stimulation effect (Rozenboim *et al.*, 2004; Al-Musawi *et al.*, 2012; Rozenboim *et al.*, 2004; Zhang *et al.*, 2012). Notably, temperature fluctuations and

light exposure during incubation modulate developmental trajectories, with potential long-term effects on metabolic programming and thermotolerance (Rozenboim *et al.*, 2004; Halevy *et al.*, 2006). This thermal modulation may serve as a preconditioning mechanism, acclimatizing the developing embryo to elevated temperatures and potentially enhancing post-hatch physiological resilience.

Previous studies have demonstrated the beneficial effects of monochromatic light exposure during incubation and post-hatch growth performance (Rozenboim *et al.*, 2004; Zhang *et al.*, 2012; Tong *et al.*, 2018). However, while photo stimulation has been widely studied under controlled conditions, its impact on broiler growth performance and survivability under heat stress conditions particularly in tropical climates, remains elusive. Despite evidence demonstrating the significance of incubation conditions in shaping post-hatch outcomes, commercial hatcheries in tropical regions typically incubate broiler eggs in complete darkness, overlooking the potential advantages of light stimulation. This gap presents an opportunity to investigate photo stimulation as a practical strategy to mitigate heat stress and enhance broiler productivity and adaptability in challenging environments.

This study aimed to investigate the effects of *in-ovo* and post-hatch exposure to GL and BL on hatching characteristics and post-hatch growth performance. We hypothesized that controlled photo stimulation during incubation and post-hatch could influence the hatching characteristics and growth performance of broilers. Our findings demonstrate that GL and BL photo stimulation significantly improved hatching characteristics and post-hatch performance, providing new insights into the role of light-mediated embryonic conditioning as an adaptive strategy for broiler production in heat-stressed environments.

MATERIALS AND METHODS

Animals and Experimental Design

The animal experiments were conducted at the Sokoine University of Agriculture (SUA), Morogoro, Tanzania. All procedures involving animals ethical clearance in this study were approved by the Sokoine University of Agriculture (SUA) with the research permit number DPRTC/R/186/59. A completely randomized experimental design was employed to investigate the effects of *in-ovo* and post-hatch photo stimulation on

the growth performance and survivability of broiler chickens. A total of 800 fertile broiler eggs, with an average weight of 65 ± 2 g were procured from a local supplier.

Incubation conditions and hatching parameters

Fertile eggs were incubated under standard conditions at 37.8°C and 60% relative humidity. Monochromatic light was provided using light-emitting diode (LED) lamps mounted on empty trays

positioned 5 cm above the eggs to ensure uniform illumination at an intensity of 0.1 W/m² at the eggshell surface. Light exposure followed a 15-minute light/15-minute dark cycle, controlled by a timer, to prevent overheating, as described by Rozenboim *et al.* (2004). The eggs were randomly allocated to three experimental groups: GL (560 nm), BL (480 nm), and a dark (control group) with 266 eggs per group. Photo stimulation was provided using LED lamps emitting either 560 nm (GL) with a half-bandwidth of 535–585 nm or 480 nm (BL). The control group was incubated in complete darkness. Cardboard partitions were used to separate different light treatment groups within the hatchery, minimizing cross-illumination between experimental units.

On embryonic day 7 (ED7), all eggs were candled to identify and remove infertile eggs and non-viable embryos. By ED17, the remaining eggs were transferred to hatching trays under their respective light treatment conditions. Upon hatching, chicks' body weights were recorded on day 0 using a digital scale with an accuracy of ± 0.01 g. Hatchability was calculated as the percentage of fertile eggs hatched to the total number of incubated eggs. Embryonic mortality was classified as early death (ED; days 0 – 7), middle death (MD; days 8 – 15), and late death (LD; days 16 – 21) based on breakout analysis at the end of incubation. Hatching time was recorded as the duration from the start of incubation to chick emergence, which was expressed in hours.

Post-hatch management and experimental setup

After hatching, chicks from each treatment group (GL, BL, and Dark) were allocated to three parallel experiments to evaluate the effects of light manipulation on growth performance:

Experiment One: A total of 240-day-old chicks, hatched from the three incubation treatments, were randomly assigned to two rooms and reared under a deep-litter system. Each room was divided into six pens, housing 20 birds per pen, allocated to each of three light treatments: GL, BL, and WL (control). The chicks were continuously photo stimulated throughout the six-week experimental period to investigate the effects of light exposure on their growth and development. Artificial light (electricity and generator back up) was provided using LED bulbs mounted 10 cm above the chicks, delivering an intensity of 0.1 W/m². The lighting regime consisted of 23 hours of illumination followed by 1 hour of darkness per day throughout the six-week experimental period.

In Experiment Two, a total of 240 chicks from three incubation treatments were investigated to assess the effects of early photo stimulation during the brooding stage on growth performance and development under varying light conditions. The chicks were exposed to three different light regimes based on their incubation light: GL, BL, or WL (control) for the first two weeks post-hatch. Following this initial period, all birds were transitioned to WL for the remaining four weeks of the experiment. Housing and management conditions were consistent with those used in experiment one to ensure uniformity.

In Experiment Three, the effects of *in-ovo* photo stimulation on post-hatch chick growth performance and development were assessed using 240 chicks subjected to three incubation treatments. All chicks were raised exclusively under WL for six weeks. To ensure consistency, the housing conditions were controlled and monitored by using a thermostat to provide optimal growth conditions. The experimental setup was identical to the conditions used in previous experiments, allowing for the evaluation of potential physiological impacts associated with light exposure during early development.

All birds in the experiments were housed in well-ventilated pens under a deep-litter system and were provided with a standard commercial diet (Irvine's Tanzania) ad libitum, with energy and protein contents specified by the manufacturer (Starter, Grower and finisher). The birds had free access to water throughout the study. Weekly measurements of BW and feed intake (FI) were recorded, with FI calculated by subtracting the remaining feed from the feed offered. The feed conversion ratio (FCR) was determined weekly as the ratio of total feed intake (g) to body weight (g) over the same period. Mortality rates were monitored and recorded to assess the survivability across the various treatment groups.

Data analysis

To assess the effects of *in-ovo* and post-hatch photo stimulation on growth performance, survivability, hatchability and embryonic mortality in broiler chickens, continuous variables such as body weight (BW), feed intake (FI) and feed conversion ratio (FCR) were analyzed using one-way ANOVA across light treatments (GL, BL and WL). Assumptions of normality and homogeneity were tested using Shapiro-Wilk and Levene's tests. Significant differences were further examined using Tukey's Honest Significant Difference (HSD) post-

hoc test. Categorical variables, including hatchability and mortality rates (late embryonic, early, middle and post-hatch mortality) were analyzed using the Chi-square test to assess differences among the treatment groups. Hatchability, expressed as the percentage of fertile eggs that hatched, and embryonic mortality rates were also compared using proportional analysis in Microsoft Excel to further illustrate differences

between light exposure conditions. All statistical analyses were performed using both Microsoft excel and JMP software (SAS Institute Inc., Cary, NC, USA). Results were considered statistically significant at $p \leq 0.05$. Data are presented as means \pm standard error of the mean (SEM) and graphical illustrations were used to visualize trends and treatment effects across groups.

RESULTS

Photo stimulation effects on hatching performance

Monochromatic light treatments had a significant impact on broiler chick hatching performance (Table 1). Statistical analysis revealed that photo stimulation significantly influenced hatching

weight ($P = 0.0007$). Eggs exposed to green light (GL) produced the heaviest chicks, followed by blue light. The GL group also exhibited the highest hatchability rate compared to the BL group and the dark control.

Table 1: Effect of monochromatic photo stimulation on hatching weight and characteristics

Treatment	Hatching weight (g)	Hatchability (%)
Dark	36.6 \pm 0.18 ^b	90.2
BL	36.6 \pm 0.17 ^b	93.2
GL	37.5 \pm 0.19 ^a	95.8
P-value	0.0007	

* Different superscript letters (^{a, b}) indicate significant differences ($P \leq 0.05$) between groups

Embryonic mortality parameters varied among the photo stimulation treatments (Table 2). Early embryonic death (EED) was significantly lower in the GL (2.0%) and BL (2.1%) groups compared to the dark control (4.48%). Mid-embryonic death (MED) was completely absent in the BL group and minimal in the GL group, while the dark control exhibited a slightly higher incidence (0.75%). In contrast, late embryonic death (LED) was highest in the GL group (3.2%), followed by the BL (1.68%) and dark control (1.49%). The proportion of pipped but unhatched embryos (PUH) was also affected by photo stimulation, with the highest rate observed in the BL group (1.26%), followed by GL (0.8%) and

the dark control (0.37%). Peak hatching activity occurred on day 19 across all treatments (Table 3), with GL showing the highest percentage, followed by the dark group and last the BL group.

Hatchability across incubation days was also influenced by light treatment (Table 3). The proportion of hatched chicks varied with the incubation day and type of light exposure. For the GL group, the majority of hatchings occurred on day 19 (89.9% of total hatchability), while in the BL and dark groups, hatchings were more evenly distributed across days 19 and 20.

Table 2: Effect of monochromatic photo stimulation on embryonic mortality and PUH percentage

Parameter	Dark (%)	BL(%)	GL(%)
Early Embryonic Death (EED)	4.48	2.1	2.0
Mid-Embryonic Death (MED)	0.75	0	0.4
Late Embryonic Death (LED)	1.49	1.68	3.2
Pipped but Unhatched (PUH)	0.37	1.26	0.8

Table 3: Distribution of hatching (%) across incubation days of broiler chickens exposed to different light treatment regimes.

Treatment	Day 18	Day 19	Day 20	Day 21
Dark (%)	0.15	33.21	56.67	0.23
BL (%)	0.29	26.65	65.85	0.47
GL (%)	0.57	86.14	8.79	0.36

Post-Hatch Growth Performance

The impact of light treatments on post-hatch growth was evaluated through three distinct experimental approaches.

Experiment One: *In-Ovo* and Post-Hatch Continuous Monochromatic Photo stimulation

Continuous monochromatic photo stimulation significantly influenced broiler growth performance over six weeks (Table 4). Birds under BL treatment exhibited the highest final BW, followed by GL ($P < 0.0001$). Weekly growth trajectories revealed

statistically significant differences emerging by week 3 and becoming more pronounced in weeks 5 and 6 (Figure 1). Birds exposed to **BL and GL** exhibited the highest body weights, which were significantly greater than those of the control group.

FI per bird over the 6-week varied significantly ($P < 0.0001$) with GL-treated birds consuming the highest intake, followed by BL and WL. FCR was most efficient in the BL group, significantly outperforming the GL and WL groups ($P = 0.0004$) over the 6-week experimental duration.

Table 4: Effects of *In-Ovo* and post-hatch monochromatic photo stimulation on broiler growth performance

	WL	BL	GL	P-value
Initial weight (g)	36.5±0.3 ^b	36.1±0.3 ^{ab}	37.2±0.3 ^a	0.0406
BW (g)	1991.0±32.2 ^b	2273.3±36.4 ^a	2207.7±42.1 ^a	<.0001
FI/birds (g)	3537.0±25.8 ^c	3642.4±21.2 ^b	3802.3±4.8 ^a	<.0001
FCR	1.8±0.02 ^a	1.64±0.03 ^b	1.77±0.003 ^a	<.0004

*Superscripts (^{a, b, c}) indicate significant differences among treatments.

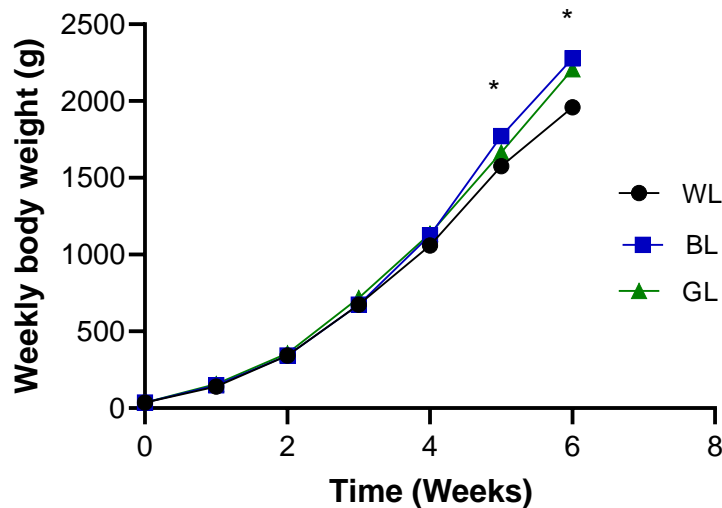


Figure 1: The effect of *in-ovo* and post-hatch monochromatic photo stimulation (GL, BL, and WL) on the weekly post-hatch BW of straight-run broiler birds over 42 days. Asterisks (*) indicate significant differences between light treatment groups.

Experiment Two: *In-Ovo* and Early Post-Hatch Photo Stimulation during Brooding

The experiment examined the effects of *in-ovo* photo stimulation and early monochromatic light exposure during the brooding stage on broiler growth performance. As presented in Table 5, broilers exposed to GL and BL during the brooding stage demonstrated significantly improved growth performance ($P = 0.0001$). After six weeks, broilers reared under GL and BL treatments during the brooding stage had significantly enhanced final body weights than those in the WL group. Specifically, birds in the GL group were heavier followed by the

BL group and the least was the WL group ($P < 0.0001$). Cumulative FI over the 6-week experimental period was significantly higher in the GL group compared to both the BL and WL groups ($P < 0.0001$). Despite the increased feed intake, the GL group exhibited a significantly improved feed conversion ratio (FCR), comparable to that of the BL group, while the W group showed a poor FCR ($P = 0.0172$).

The weekly BW data demonstrated that chicks treated with GL and BL consistently exhibited higher body weights from week 3 onward, with the difference becoming more pronounced during the

later stages of growth. Statistical analysis revealed significant differences in BW between treatment

groups from weeks 4 to 6 ($P < 0.001$), as shown in **Figure 2**.

Table 5: Effects of pre-and early post-hatch (during brooding) monochromatic photo stimulation on post-hatch broiler growth performance

	WL	BL	GL	P-value
Initial weight (g)	36.5±0.3 ^{ab}	36.1±0.3 ^b	37.2±0.3 ^a	0.0463
BW (g)	1937.9±32.0 ^b	2107.8±44.5 ^{2.4 a}	2220.4±39.3 ^a	<.0001
FI/birds (g)	3459.3±6.0 ^b	3483.6±27.8 ^b	3662.7±12.8 ^a	<.0001
FCR	1.82±0.03 ^a	1.71±0.03 ^b	1.69±0.04 ^b	<.0172

*Superscripts (^{a, b, c}) indicate significant differences among treatments.

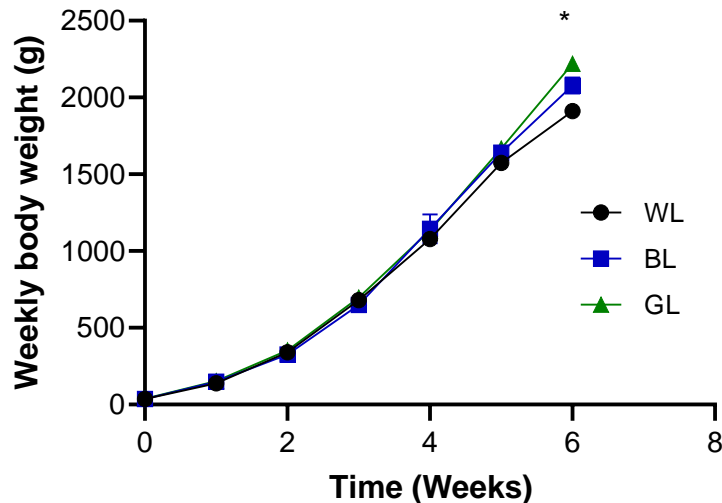


Figure 2: The effect of *in-ovo* and early post-hatch during the brooding stage monochromatic photo stimulation (GL, BL, and WL) on the weekly post-hatch BW of straight-run broiler birds over 42 days. Asterisks (*) indicate significant differences between light treatment groups.

Experiment Three: Effect of *In-Ovo* Photo stimulation on Post-Hatch Growth Performance of Broiler Chickens

In-ovo photo stimulation significantly enhanced final body weight, with birds subjected to BL showing the heaviest overall weight followed by GL and the least being ($P < 0.0001$) (Table 6). Weekly growth analysis revealed that birds treated with BL and GL exhibited significantly higher body weights

throughout the experimental period. The differences became evident from week 3 and remained significantly greater through week 6 (Figure 3: $P < 0.0001$). Feed intake (FI) per bird for the whole experimental duration (6 weeks) was greatest in the GL-treated group, surpassing both BL and dark treatment groups ($P < 0.0001$). Furthermore, feed utilization was most favorable in the BL-treated birds followed by GL and WL the differences being statistically significant ($P < 0.0001$).

Table 6: Effects of *in-ovo* monochromatic photo stimulation on post-hatch broiler growth performance

	WL	BL	GL	P-value
Initial weight (g)	36.8±0.3	37.3±0.2	37.4±0.3	0.3037
BW (g)	2117.2±32.4 ^b	2409.3±38.3 ^a	2363.1±38.4 ^a	<.0001
FI/birds (g)	3555.5±13.5 ^b	3557.2±23.9 ^b	3789.2±5.0 ^a	<.0001
FCR	1.71±0.02 ^a	1.5±0.02 ^b	1.63±0.002 ^a	<.0001

*Superscripts (^{a, b}) indicate significant differences among treatments.

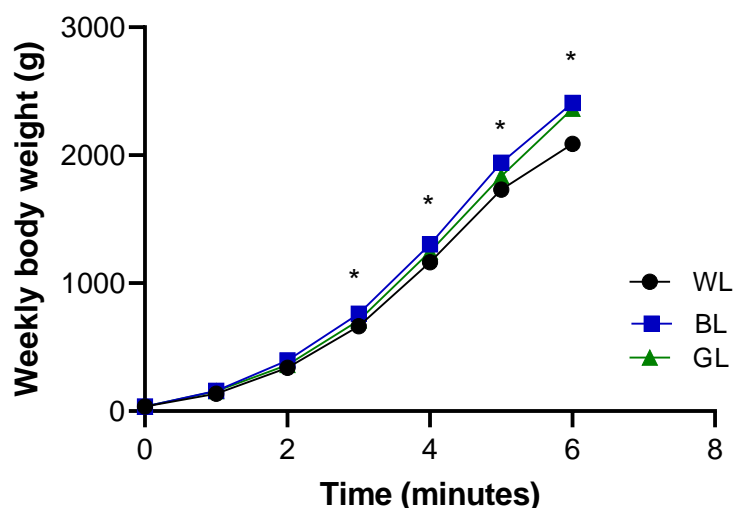


Figure 3: Effect of *in-ovo* photo stimulation (GL, BL, and WL) on the weekly post-hatch body weight of birds throughout 42 days. Asterisks (*) denote significant differences between light treatment groups ($P < 0.005$).

Across all experiments, survivability was consistently higher in birds exposed to GL and BL treatments compared to those under WL conditions, with BL exhibiting the lowest mortality rates throughout the study.

DISCUSSION

In this study, we explored the effects of monochromatic photo stimulation on broiler chick hatching performance (hatching weight and Hatchability), with a particular focus on the impact of GL and BL treatments. The results indicate that photo stimulation significantly influenced hatching weight and hatchability, with GL exposure leading to the heaviest chicks and the highest hatchability rate. The BL group also showed improved hatchability compared to the dark control group. These findings are consistent with previous studies that demonstrated that monochromatic light, especially GL, enhances embryonic development and hatchability (Shafey and Al-Mohsen, 2002; Rozenboim *et al.*, 2004; Tong *et al.*, 2018; Sobolewska *et al.*, 2019; Bai *et al.*, 2016). Furthermore, the data reveal that GL and BL treatments significantly reduced EED, compared to the dark control. Notably, the BL treatment showed a complete absence of MED, and GL had minimal MED, further supporting the hypothesis that specific wavelengths of light have a protective role during early embryonic stages. This aligns with findings from Tong *et al.* (2018), who proposed that monochromatic light modulates developmental pathways through specific photoreceptors. Eggshell characteristics such as pigmentation, thickness and porosity play a role in modulating the stimulation of the developing embryo (Shafey *et al.*, 2005). However, Shafey and Al-Mohsen (2002) demonstrated that GL illumination influenced

embryonic growth rates independently of these physical eggshell properties, suggesting that light penetrates the shell pores and is received via photoreceptors inducing a response.

Although both GL and BL treatments exhibited lower early mortality, the GL group showed a slightly higher incidence of LED, suggesting a potential trade-off between early development enhancement and later-stage growth. This observation is in line with Zhang *et al.* (2014), who suggested that GL exposure could stimulate growth factors such as growth hormone (GH) and insulin-like growth factors (IGF-1) to enhance early development but may also influence late-stage developmental processes less favorably. The survival data observed in this study support previous findings indicating that *in ovo* photo stimulation enhances the adaptability of broilers to environmental stressors (Halevy *et al.*, 2006; Zhang *et al.*, 2014). Despite this, the GL group demonstrated the highest peak hatching activity on day 19. This accelerated hatching timing could indicate an enhancement of embryonic metabolic processes through light exposure, possibly by influencing the pineal gland and internal biological rhythms, as proposed by Rozenboim *et al.* (2013).

The timing of peak hatching activity, particularly on day 19 for the GL group, suggests that photo stimulation may hasten embryonic development.

This is supported by Shafey (2004), who observed similar shifts in hatching timing under light exposure. Additionally, the findings suggest that light exposure, particularly GL, may influence the embryo's metabolic processes by affecting the endocrine system. Previous studies by Rozenboim *et al.* (2013) and Zhang *et al.* (2014) have indicated that GL photo stimulation can upregulate the expression of growth-related genes, including hypothalamic growth hormone-releasing hormone (GHRH), growth hormone (GH) and insulin-like growth factor 1 (IGF-1), particularly from embryonic days (ED) 12 to 14. Such upregulation is likely to promote accelerated growth and improved hatching performance, which could explain the enhanced hatchability and reduced early embryonic mortality observed in our GL-treated group.

In Experiment One, continuous monochromatic photo stimulation significantly improved broiler growth performance, with birds under BL and GL treatments exhibiting superior final BW compared to the WL (control) group. These findings are consistent with those of Zhang *et al.* (2012) and Rozenboim *et al.* (2004), who demonstrated the positive effects of monochromatic lighting on muscle development and growth regulation in broilers. Consistent data in turkeys found enhanced post-hatch body weight and earlier hatchability in female turkey poultry stimulated with GL (Rozenboim *et al.*, 2003). These findings support earlier reports that photo stimulation enhances the pectoral myofiber area (Cao *et al.*, 2008) as well as breast and thigh muscle fiber diameter (Queenie *et al.*, 2018) in broilers, compared to other light wavelengths. The most efficient FCR observed in the BL group supports the hypothesis of Cao *et al.* (2008) that BL promotes metabolic efficiency, potentially by influencing hormonal pathways that regulate energy utilization. This study supports previous findings demonstrating the beneficial effects of monochromatic light exposure during incubation or post-hatch development, particularly in enhancing feed efficiency (Rozenboim *et al.*, 2004; Zhang *et al.*, 2012). The significantly higher FI recorded in the GL group may suggest increased appetite stimulation under green wavelengths, which when combined with improved FCR, results in enhanced overall performance. Together, these results highlight the potential of continuous monochromatic photo stimulation particularly BL and GL as a viable strategy for optimizing broiler production by promoting better weight gain and feed efficiency.

Experiment two evaluated the effect of photo stimulation during the critical early post-hatch

brooding period. The enhanced growth performance observed in birds exposed to GL and BL during brooding aligns with Halevy *et al.* (2006) and (Rozenboim *et al.*, 1999, 2004), who emphasized the importance of early developmental windows for physiological programming through environmental cues. The findings suggest that early exposure to monochromatic light may promote satellite cell proliferation and differentiation, thereby enhancing muscle growth trajectories. Both GL and BL groups exhibited significantly improved BWs and FCRs compared to WL, indicating that early post-hatch light treatments can have lasting impacts on metabolic regulation and nutrient utilization. These observations are supported by Rozenboim *et al.* (2013), who reported that early light environments can induce long-term physiological adaptations. Thus, the strategic application of GL and BL during brooding and early post-hatch could be an effective approach to enhance productivity and feed efficiency in commercial poultry operations.

In experiment three, *in-ovo* photo stimulation alone resulted in significantly enhanced post-hatch performance, with BL-exposed birds achieving the highest final BW and most favorable FCR. These findings corroborate those of Zhang *et al.* (2014) and Tong *et al.*, 2018, who reported that light exposure during embryogenesis influences post-hatch physiology and growth patterns. The superior feed efficiency observed in BL-treated chicks further suggests an underlying shift in metabolic dynamics, possibly driven by early light-induced epigenetic modifications. The fact that these effects were observed in the absence of post-hatch light exposure underlines the importance of embryonic light environments in shaping post-hatch performance. These results emphasize the potential of *in-ovo* photo stimulation as a non-invasive, cost-effective intervention for enhancing broiler growth and feed utilization.

Across all three experiments, broilers exposed to GL and BL treatments consistently demonstrated higher survivability and improved performance metrics compared to those reared under WL. This pattern suggests that monochromatic light, especially during embryonic and early post-hatch development, may confer resilience to environmental stressors, potentially through modulation of stress response pathways and immune function. Overall, the findings support the strategic use of monochromatic light treatments particularly blue and green wavelengths as a promising tool for enhancing growth, feed efficiency, and survivability in broiler production systems.

Therefore, exposure to green light (GL) during incubation significantly improved hatching outcomes, producing the heaviest chicks and the highest hatchability rates. Both GL and blue light (BL) treatments effectively reduced early and mid-embryonic mortality compared to the dark control, suggesting enhanced embryonic viability. Peak hatching activity occurred earlier in the GL group, indicating accelerated embryonic development. Post-hatch, continuous exposure to BL light yielded the highest final body weight and the most efficient (FCR), followed closely by GL, while birds under

white light (control) consistently resulted in inferior growth metrics. Photo stimulation applied *in-ovo* alone significantly enhanced post-hatch growth performance, with birds exposed to blue light (BL) showing the highest final body weights and the best feed efficiency. Collectively, these findings suggest that incorporating specific wavelengths of monochromatic light, particularly blue and green, during incubation and early brooding stages is an effective strategy to enhance hatching outcomes, and survivability and optimize growth performance in broiler production systems.

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CONFLICT OF INTEREST

Authors do not have any conflict of interest

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