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Light source effects on egg production and performance modeling of kub chickens

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ABSTRACT

Lighting intensity strongly influences reproductive physiology and productivity in laying hens. This study examined the effects of different light intensities and lamp types on egg production traits in KUB chickens and modeled production dynamics using nonlinear regression. Four treatments were tested: control, 5-watt blue LED, 5-watt incandescent, and 5-watt white LED. Daily egg count, Hen Day Production (HDP), total egg weight, and average egg weight were analyzed using one-way ANOVA and Tukey's HSD. Results showed that higher light intensities significantly increased egg count, HDP, and total egg weight ($p < 0.05$), while average egg weight remained unchanged. Logistic models best fit incandescent and white LED groups, whereas blue LED data aligned with an Exponential model. White LEDs offer an energy-efficient option for improving productivity.

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INTRODUCTION

The physiological performance of animals is greatly affected by environmental factors such as light, pH, temperature, and relative humidity. Among these, light is very important for controlling the growth, reproduction, and behaviour of chickens via means of circadian and neuroendocrine mechanisms (Geng et al., 2022; Yang et al., 2022). It controls the release of gonadotropin and melatonin, two hormones necessary for ovulation, follicular growth, and general reproductive effectiveness (Sun et al., 2023; Yang et al., 2022). The length and spectrum of light have an impact on laying hens' feed intake, metabolic processes, and egg–laying cycles (Abdel–Moneim et al., 2024; Wei et al., 2020). Thus, in chicken production systems, optimizing lighting conditions is a key management tactic to raise output and guarantee animal welfare.

Numerous studies have examined how artificial lighting affects poultry productivity over the past few decades (Pap et al., 2024; Soliman et al., 2023). However, findings are still contradictory, though, particularly when it comes to how different light spectra and lamp types affect layer performance (Sheir et al., 2025). Energy–efficient light–emitting diodes (LEDs), which emit wavelengths like blue and white light, are gradually replacing conventional incandescent bulbs (Sheir et al., 2025; Wei et al., 2020). Physiological processes, including egg formation, shell quality, and total production rate, can all be significantly impacted by these spectrum variances (de Souza Granja Barros et al., 2024; Fernandes et al., 2022). However, most of the current research focuses on commercial layer strains in controlled settings; thus, little is known about how different light sources impact native or enhanced species bred in tropical climates.

KUB (Kampung Unggul Balitbangtan) chickens, a genetically improved Indonesian native breed, represent an increasingly important poultry resource for meeting current community demands for affordable and sustainable animal protein. Their widespread adoption among smallholder farmers reflects their adaptability to tropical environments, efficient feed utilization, and stable reproductive performance, making them suitable for supporting household income and local egg supply (Insani et al., 2022; Sartika & Iskandar, 2019). Despite their growing role in community-based poultry systems, systematic research on how light sources influence their production dynamics remains limited. This gap highlights the need for integrated studies that combine physiological performance indicators with predictive modelling approaches to elucidate the light–productivity relationship in KUB chickens under practical tropical farming conditions. Addressing this issue is essential for optimizing management strategies based on locally developed genetic resources.

Growth and performance models provide a quantitative framework for describing and predicting the biological response of poultry production systems (Mancinelli et al., 2023). These models can be represented by nonlinear models e.g., Exponential, Gompertz, and Logistic functions, which allow researchers to estimate critical parameters such as growth rate, production peak, and asymptotic performance that provide valuable insight into the dynamics of poultry productivity (Narinç et al., 2017; Reis et al., 2023; Setiaji et al., 2023). Therefore, integrating such modelling approaches with experimental data enables a more accurate understanding of how environmental factors and management interventions, including lighting systems, can influence egg production patterns over time.

This study integrates empirical performance of egg production data and nonlinear modelling to evaluate the influence of different light sources on KUB chicken productivity and to identify the most representative model of egg production dynamics. This study analyses egg production traits, including egg count, total egg weight, average egg weight, and Hen Day Production Rate (HDP) under various lighting conditions, including incandescent, white LED, blue LED, and control lighting conditions. By combining experimental observation of egg production traits and predictive modelling, this research aims to provide a comprehensive understanding of how light sources affect egg production in KUB chicken, contributing to optimized lighting management strategies for sustainable poultry farming in Indonesia.

RESEARCH METHODS

Research Design

This study employed an experimental research design conducted from June to July 2025 at the Center for Agricultural Implementation and Modernization (BRMP) in Kayu Agung, South Sumatra. Four lighting treatments were applied to assess their effects on the productivity of KUB laying hens. The treatments consisted of natural lighting as the control, 5-watt white LED lighting, 5-watt incandescent lighting, and 5-watt blue LED lighting, all arranged under a controlled light–dark cycle of 15 hours of light and 9 hours of darkness. The experimental period lasted for 20 days following a 1-day adaptation phase. All hens were housed in enclosed cages measuring 2 m × 4 m × 2.5 m, with each lighting device installed approximately 1 meter above the cage floor to ensure uniform light distribution across all treatment groups (Table 1). The research design was adapted and modified from the methodology of Putra et al. (2022).

Table 1. Research design

Lighting Source	Lamp Power (W)	Light Regime (L:D)	Experimental Duration
Control	-	15:9	20 days (+1 day adaptation)
5–watt Blue LED	5	15:9	20 days (+1 day adaptation)
5–watt incandescent	5	15:9	20 days (+1 day adaptation)
5–watt White LED	5	15:9	20 days (+1 day adaptation)

Population and Samples

The research population consisted of KUB-type laying hens in their productive phase. A total of 96 chickens were used, comprising 3 roosters and 21 hens per treatment group, resulting in 24 chickens assigned to each of the four lighting treatments. The sample distribution followed a completely grouped design in which all treatment groups were maintained under identical management conditions except for the lighting intervention. This approach ensured that any differences in egg production performance were attributable solely to the lighting treatments.

Instruments

The primary instruments utilized in this study included 5-watt white LED lamps, 5-watt incandescent bulbs, and 5-watt blue LED lamps as lighting treatments, as well as enclosed cage units equipped with feeders and drinkers. A digital scale with 0.01 g accuracy was used to measure egg weight, while a digital lux meter was employed to measure light intensity at a standardized height of 1 meter above the cage floor. Additionally, eggs were stored in coded trays to facilitate treatment-based identification and replication tracking. These instruments collectively ensured accurate and consistent data collection throughout the experiment.

Procedures

The experiments were conducted over a period of 20 days, with a one–day adaptation period preceding them. In accordance with the prescribed treatments, a total of 24 KUB chickens were housed in enclosed cages measuring 2 m × 4 m × 2.5 m (length × width × height). Each cage was equipped with a specific lighting setup, in which the light source was positioned at the center of the enclosure at a distance of approximately 1 meter above the cage floor surface to ensure uniform light distribution. The hens were fed 120 grams per head per day, which was divided into two feedings: 60 grams in the morning (7:00 AM) and 60 grams in the afternoon (4:00 PM). Throughout the duration of the research, the chickens were provided with drinking water on an *ad libitum* basis to guarantee that their fluid requirements were consistently satisfied. Data regarding egg production performance was collected daily from the beginning of rearing to the end of the observation period. Hen Day Production (HDP), egg weight, and light intensity were among the parameters that were observed. Every morning at 10:00 AM., eggs were collected and subsequently weighed using a digital scale with an accuracy of 0.01 grams. To facilitate data monitoring, the weighed eggs were stored in egg trays that were coded based on treatment and replication. Furthermore, to guarantee data consistency, lux intensity was simultaneously obtained using a digital lux meter about 1 meter from the surface. The lighting treatment employed in this study was a version of the technique established by Putra et al. (2022), adapted to the field conditions at the Kayu Agung BRMP Experimental Garden in South Sumatra. The primary variables in this study were Hen Day Production (HDP) and egg production traits, including daily egg count, total weight of eggs, and average of eggs weight for each group. Hen Day Production was calculated using this formula (Hastuti et al., 2024):

$$\textbf{HDP}\ (\%) = \frac{\textbf{Number of egg production}}{\textbf{Number of chicken}} \times \textbf{100\%}$$

Data Analysis

The analysis of data was performed in three phases sequentially, including descriptive, inferential, and nonlinear modelling techniques to assess the impact of light sources on the productivity of KUB–type laying hens. The comprehensive analysis was performed utilizing the recent version of R software (version 4.4.2) supplemented with the programs *car* (Fox et al., 2001), *dplyr* (Wickham et al., 2014), *FSA* (Ogle, 2015), *lme4* (Bates et al., 2003), *lmerTest* (Kuznetsova et al., 2013), *emmeans* (Lenth, 2017) , *minpack.lm* (Elzhov et al., 2022), *Metrics* (Hamner & Frasco, 2012) and *ggplot2* (Wickham et al., 2007). Each data point was displayed as mean ± standard deviation (SD) for each parameter were derived from the estimated marginal means (EMMEANS) using *emmeans* package obtained from the mixed model for each treatment.

A linear mixed model (LMM) (Gałecki & Burzykowski, 2013) was utilized for inferential statistical analysis, employing the *lme4* and *lmerTest* packages. The utilized model was structured as follows:

$$Y_{ij} = \mu + \alpha_i + (1 \mid Day_j) + \varepsilon_{ij}$$

where Y_{ij} represents the observed value (HDP, average egg weight, or total egg weight) for the *i* treatment on the *j* day, α_i denotes the fixed effect of the light treatment, while Day_j is included as a random effect to account for variation across observation days. The normality of data distribution was evaluated using the Shapiro–Wilk test, and the Levene's test was used to check the homogeneity of data variances using the *car* packages. The one – way Analysis of Variance (ANOVA) was used to test the significance of treatment effects, while pairwise comparisons among groups were performed using Tukey's HSD test based on the *emmeans* approach at a significance level of α=0.05 if the data followed normal distribution, otherwise, the Kruskal–Wallis test was utilized as a non–parametric alternative, succeeded by Dunn's post hoc test using *FSA* package at α=0.05.

Next, nonlinear regression modelling describes egg production performance traits during observation. The Exponential, Logistic, and Gompertz growth models (Ghavi Hossein-Zadeh, 2025; Hifzan et al., 2024) were built using daily data and the *nlsLM* tool in *minpack.lm* package. Model performance was assessed using Akaike Information Criterion (AIC) and Root Mean Square Error (RMSE) values, with the optimal model having the lowest AIC and smallest RMSE values (Hifzan et al., 2024; Hrehova et al., 2025).

RESULTS

Light Intensity Effect on KUB Chicken Egg Production Performance

Daily averages of KUB chicken egg production and related performance traits are presented in Table 2. Significant differences were observed among treatments in daily egg count ($p = 1.7 \times 10^{-10}$) (Table 2). The control group (50–120 lux) produced the lowest number of eggs (5.5 ± 1.9 eggs day^{-1}). Chickens exposed to 5-watt blue LED lighting (150–200 lux) showed a higher daily egg production (8.5 ± 2.7 eggs day^{-1}). The highest daily egg production was recorded under 5-

watt incandescent (450–600 lux) and 5-watt white LED (350–500 lux) lighting, producing 9.9 ± 2.5 and 10.0 ± 2.4 eggs day^{-1}, respectively.

Table 2. Daily averages of KUB chicken egg production and related performance traits

Treatment	Light Intensity (lux)				Parameters	
	Min	Max	Daily average of egg count ± SD	Daily average of HDP (%) ± SD	Daily average of each egg weight (gr) ± SD	Daily average of total egg weight (gr) ± SD
Control	50	120	$5.5 \pm 1.9^{b*}$	$26.2 \pm 9^{b*}$	44.7 ± 1.8^{a}	$245.0 \pm 82.9^{b*}$
5–watt Blue LED	150	200	$8.5 \pm 2.7^{ab*}$	$40.5 \pm 12^{a*}$	45.4 ± 1.8^{a}	$386.9 \pm 117.3^{a*}$
5–watt incandescent	450	600	$9.9 \pm 2.5^{a*}$	$47.4 \pm 17^{a*}$	46.0 ± 2.8^{a}	$456.4 \pm 162.8^{a*}$
5–watt White LED	350	500	$10 \pm 2.4^{a*}$	$47.6 \pm 11^{a*}$	44.6 ± 0.9^{a}	$445.2 \pm 102.4^{a*}$
p–value	–	–	1.7×10^{-10}	1.7×10^{-10}	7.5×10^{-2}	7.2×10^{-11}

Note: Values are reported as mean ± SD. Asterisks (*) indicate metrics with statistically significant changes between treatments using one–way ANOVA ($p < 0.05$). Significant differences between treatments are shown by different superscript letters within the same column using Tukey's HSD test ($p < 0.05$).

Hen Day Production (HDP, %) also differed significantly among treatments ($p = 1.7 \times 10^{-10}$). The lowest HDP value was observed in the control group (26.2 ± 9%), while higher HDP values were recorded under blue LED (40.5 ± 12%), incandescent (47.4 ± 17%), and white LED (47.6 ± 11%) treatments.

Daily total egg weight showed a similar pattern, with significant differences among treatments ($p = 7.2 \times 10^{-11}$). The control group exhibited the lowest total egg weight (245.0 ± 82.9 g day^{-1}), followed by the blue LED treatment (386.9 ± 117.3 g day^{-1}). The highest total egg weights were recorded under incandescent (456.4 ± 162.8 g day^{-1}) and white LED (445.2 ± 102.4 g day^{-1}) lighting.

In contrast, the average weight of individual eggs did not differ significantly among treatments ($p = 0.074$). Mean egg weights ranged from 44.6 ± 0.9 g to 46.0 ± 2.8 g across all lighting conditions.

Modelling of KUB Chicken Egg Production Performance Traits under Various of Light Intensity

Daily averages of egg production performance traits were fitted using nonlinear regression models, including Logistic, Exponential, and Gompertz functions (Figures 1–4). Model selection was based on Akaike Information Criterion (AIC) and Root Mean Square Error (RMSE), with lower values indicating better model performance.

For daily egg count, the Logistic model provided the best fit for the control, incandescent, and white LED treatments (AIC = 82.1–87.8; RMSE = 1.54–1.78), whereas the Exponential model best described the pattern under blue LED lighting (AIC = 9.38; RMSE = 2.17) (Figure 1).

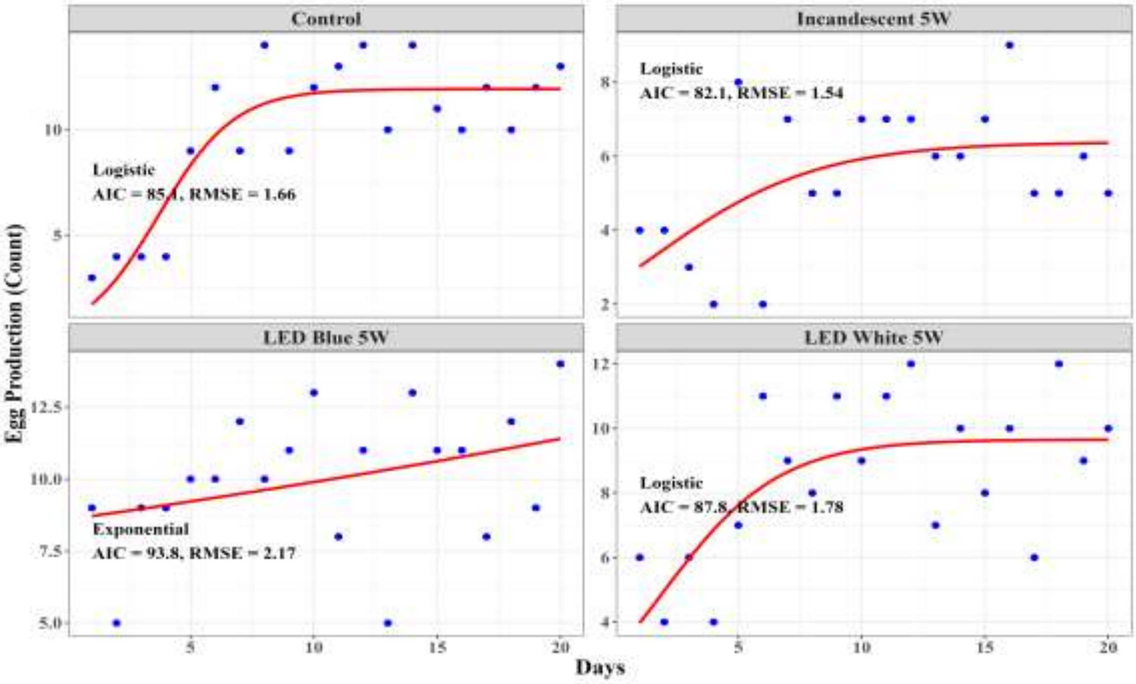

Figure 1. Best–fit model for daily average of egg count

Similar model-fitting patterns were observed for Hen Day Production (%) (Figure 2) and total daily egg weight (Figure 3). Logistic models best characterized the control, incandescent, and white LED treatments, while the Exponential model was more appropriate for the blue LED treatment. The incandescent lighting treatment yielded the lowest AIC (–39.6) and RMSE (0.07), indicating the most consistent production performance.

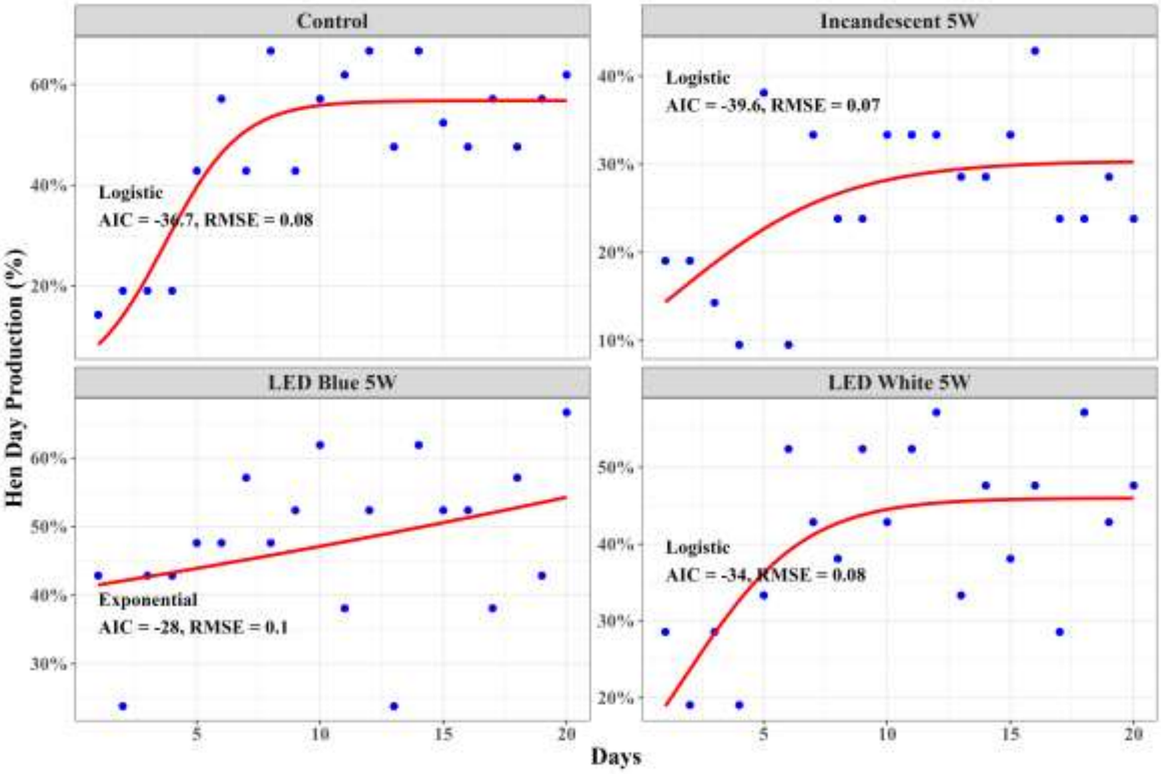

Figure 2. Best–fit model for daily average of Hen Day Production (%)

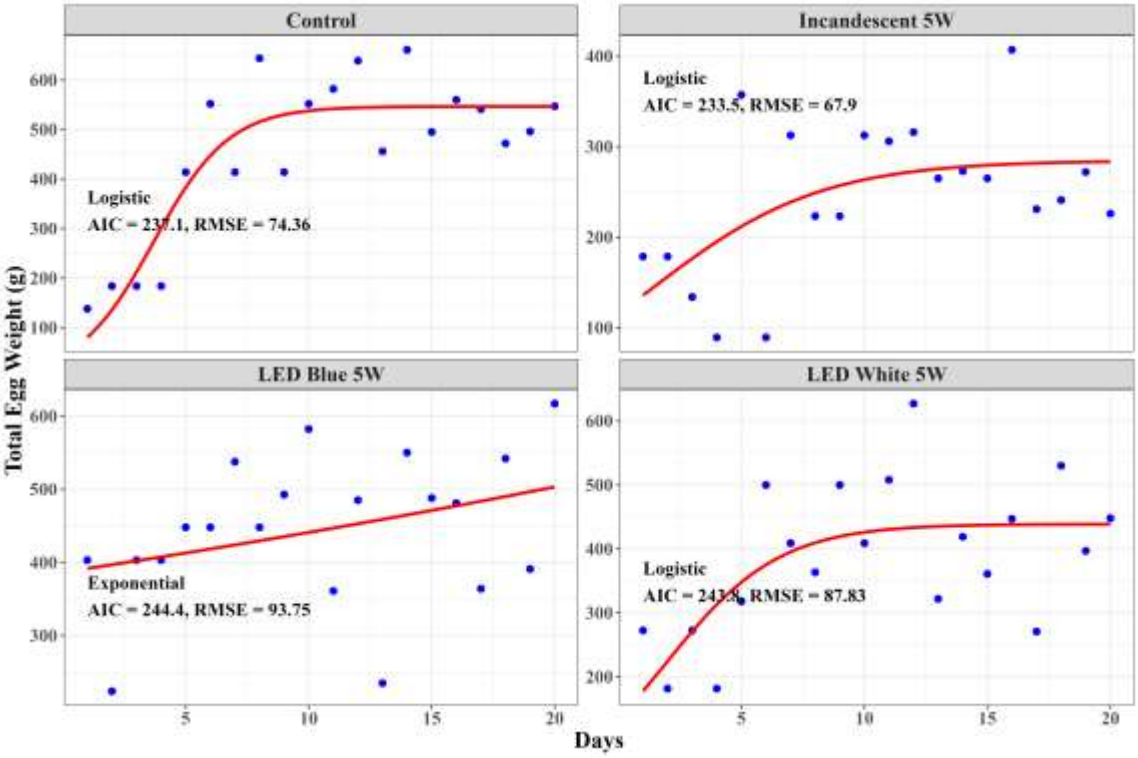

Figure 3. Best–fit model for daily average of total weight of egg

For average individual egg weight, the Exponential model provided the best fit across all treatments (AIC = 56.57–99.85; RMSE = 0.86–2.40), indicating a gradual increase without a clear plateau (Figure 4).

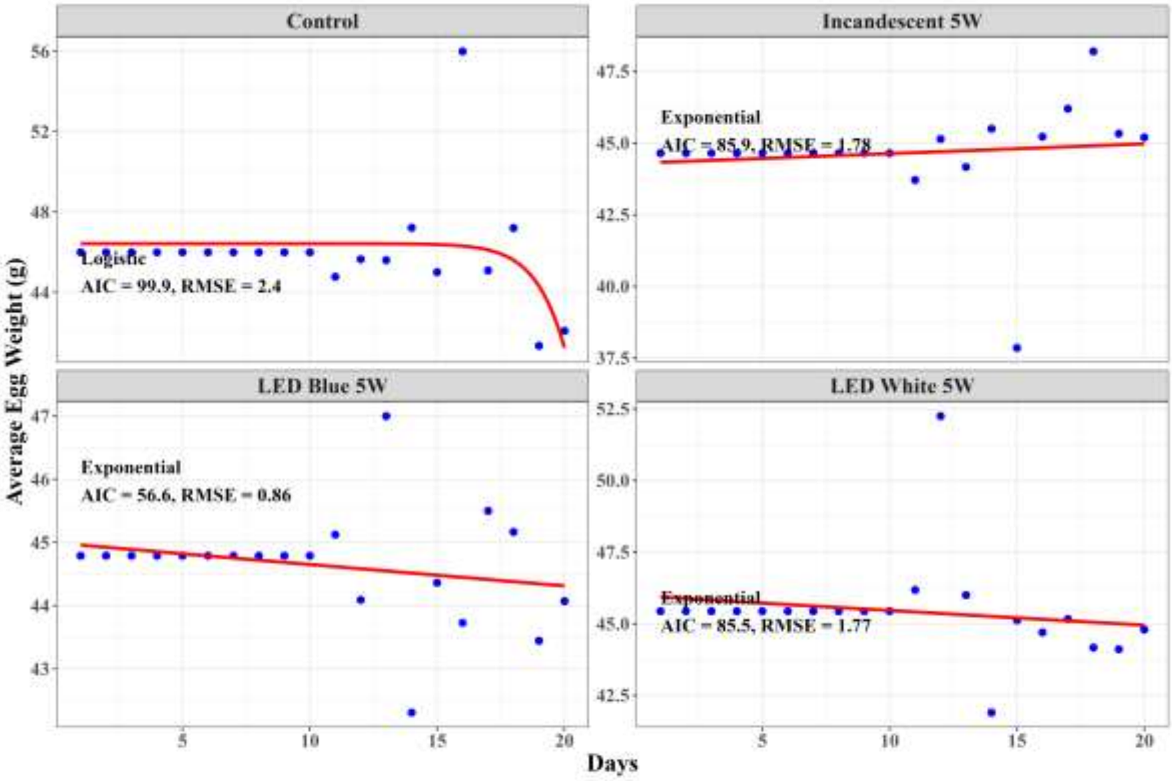

Figure 4. Best–fit model for daily average of each weight of egg.

DISCUSSION

The present results demonstrate that increasing light intensity substantially enhances egg production frequency and Hen Day Production in KUB chickens. The markedly lower egg output and HDP observed under low light intensity (control group) indicate insufficient photostimulation to support optimal reproductive activity. In contrast, higher light intensities, particularly under incandescent and white LED lighting, promoted greater laying frequency and flock-level productivity.

These findings align with previous studies reporting that increased light intensity enhances reproductive output by activating the hypothalamic–pituitary–gonadal (HPG) axis, leading to increased secretion of luteinizing hormone (LH) and follicle-stimulating hormone (FSH), which regulate follicular development and ovulation (Sheir et al., 2025; Erensoy et al., 2021). The elevated HDP values observed under incandescent and white LED treatments further suggest that lighting conditions influence not only ovulation initiation but also the maintenance of a stable laying rhythm.

Spectral composition appears to play a critical role alongside light intensity. Incandescent and white LED lights emit broader spectra, including longer wavelengths that are more effective at stimulating avian deep-brain photoreceptors. These photoreceptors, together with retinal photostimulation, regulate circadian rhythms and reproductive hormone cycles, enabling sustained egg production (Zaguri et al., 2020). Similar observations have been reported by Hanlon et al. (2020) and Rozenboim et al. (2022), who highlighted the role of photopigments such as melanopsin, neuropsin (Opsin 5), and vertebrate ancient opsin in mediating reproductive photostimulatio

The predominance of Logistic models under incandescent and white LED lighting reflects a biologically realistic reproductive trajectory, characterized by an initial adaptation phase, rapid production increase, and eventual stabilization as physiological limits are reached. This pattern mirrors the progressive activation of the HPG axis in response to effective photostimulation (Oso et al., 2022). Conversely, the Exponential pattern observed under blue LED lighting suggests a slower and less synchronized reproductive response, likely due to preferential stimulation of retinal photoreceptors and altered melatonin and gonadotropin-inhibitory hormone signaling pathways (de Souza Granja Barros et al., 2024).

The absence of significant differences in individual egg weight across treatments indicates that light intensity primarily modulates egg-laying frequency rather than egg size. This finding supports previous reports that egg weight is more strongly influenced by genetic background and nutritional status than by environmental lighting conditions (Bahuti et al., 2023; Erensoy et al., 2021). The exponential trend observed in egg weight modelling further suggests stable metabolic regulation of yolk and albumen deposition, independent of photostimulation intensity (de Souza Granja Barros et al., 2024). Overall, the results indicate that optimized light intensity and spectral quality enhance reproductive rhythm and production efficiency in KUB chickens, improving the quantity of egg output without compromising egg quality.

This study provide valuables findings that the influenve of light intensity strongly affect the egg production performrance in quantity aspect (e.g., number of laying eggs, total weight of eggs and Hen Day Production (%)) rather that the quality aspect (i.e., average of each weight of egg). However, several limitations should be acknowledged. First, the experiment was conducted in a relatively short observation period that may not fully reveal the long – term physiological adaptation or concerning into the seasonal photoperiodic responses. Furthermore, prolong observation time could help to clarify the performance of improvement under incandescent and white LED remain consistent or plateau over extended production periods.

Second, only the intensity and type of light source were examined, while other photoperiodic parameters such as light duration, wavelength distribution and flicker frequency were absent. These factors could interactively explain more robust the reproductive synchronization factors such as the hypothalamic–pituitary–gonadal (HPG) axis and overall productivity aspect. For example, as observed by Oso et al. (2022) that red and longer–wavelength light stimulates extra–retinal photoreceptors effectively and lead to greater GnRH synthesis and reproductive activation.

Third, although egg production features were thoroughly examined, this study omitted hormonal or molecular assessments (e.g., GnRH, LH, FSH, melatonin, or gene expression of opsins) that could directly corroborate the physiological mechanisms driving the observed trends. Including assessments of endocrine function and gene expression would establish more robust causal relationships among light quality, photoreceptor activity, and reproductive consequences. Furthermore, as observed by Wang et al. (2024) that specific red–light wavelength enhances plasma estradiol (E2) and follicle–stimulating hormone (FSH) levels in reproductive tissues in avian group, directly correlating with enhanced egg production.

Fourth, environmental factors like temperature, humidity, and feed intake were kept the same across the board, but the impact of illumination treatments on these factors were not systematically studied. Future research that combines multivariate modelling of environmental and management elements could improve the accuracy of predictions for production efficiency. Lastly, incandescent light demonstrated the best biological responses, but it isn't practical for modern poultry systems since it wastes energy and gives off too much heat. Future study should investigate optimised LED systems that emulate the advantageous red–spectrum wavelengths of incandescent lamps while ensuring low energy consumption and little heat production. In conclusion, forthcoming study ought to concentrate on formulating integrated light management strategies by incorporating optimised light spectra, photoperiods, and intensity controls in order to improve the production and welfare of KUB chickens. To understand how artificial lighting conditions can sustainably control KUB chickens' reproduction traits and make production more efficient, the combination of physiological, behavioural, and molecular approaches is needed.

CONCLUSION

The findings indicated that varying light intensities—control, blue LED light, incandescent light, and white LED light—significantly influenced egg production features, including daily egg count, Hen Day Production (%), and total egg weight, although egg size remained same. Logistic and exponential models effectively characterised biological production patterns, demonstrating that optimal lighting expedites reproductive activation and stabilises laying rhythm through increased photostimulation of the hypothalamic–pituitary–gonadal axis. Future research should concentrate on creating energy–efficient LED systems that replicate the advantageous red spectrum of incandescent light to enhance productivity and animal welfare sustainably.

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