



RESEARCH ARTICLE

Effects of Tetrachromatic Full-Spectrum LED Lighting on Growth Performance, Physiological Stress and Antioxidant Levels in Broiler Chickens: Implications for Welfare and Sustainable Poultry Production

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Abstract

Background and Objective: The light environment is a critical yet often underappreciated factor influencing poultry physiology, welfare and productivity. This study aimed to evaluate the effects of tetrachromatic full-spectrum PhysLite® LED lighting, designed to mimic the natural visual perception of chickens, on growth performance, physiological stress and antioxidant status in broiler chickens.

Materials and Methods: A total of 60 day-old broiler chicks were randomly allocated to two treatment groups: (1) Conventional white LED lighting (control) and (2) Tetrachromatic full-spectrum PhysLite® LED lighting. Body weight was recorded daily over a 30-day experimental period. On day 30, blood samples were collected to determine serum corticosterone levels and antioxidant indices, including superoxide dismutase (SOD), catalase (CAT) and malondialdehyde (MDA), using enzymatic colorimetric methods.

Results: Broilers reared under tetrachromatic full-spectrum lighting exhibited significantly higher final body weight compared to the control group. Additionally, corticosterone concentrations were markedly reduced, indicating lower physiological stress. Antioxidant analysis revealed increased SOD activity, along with decreased CAT activity and MDA concentrations, suggesting improved redox balance and reduced oxidative stress in birds exposed to PhysLite® lighting. Furthermore, the alignment of the lighting system with the tetrachromatic visual sensitivity of chickens likely contributed to enhanced visual comfort and behavioral stability.

Conclusion: Tetrachromatic full-spectrum PhysLite® LED lighting significantly improves growth performance, mitigates physiological stress and enhances antioxidant status in broiler chickens. These findings highlight its potential as a welfare-oriented and sustainable lighting strategy for optimizing productivity and health in modern poultry production systems.

INTRODUCTION

The poultry industry has undergone substantial expansion in recent decades, primarily driven by the increasing global demand for affordable animal protein. Despite this growth, the sector continues to encounter significant challenges related to production efficiency, animal welfare and environmental sustainability. Among the environmental factors influencing poultry production, the lighting system employed in intensive housing conditions plays a pivotal role. Conventional lighting systems, typically characterized by limited or monochromatic spectral outputs, do not adequately replicate the natural light environment required to support optimal physiological and behavioral functions in chickens¹.

Light functions not only as a visual stimulus but also as a critical regulator of endocrine, metabolic and reproductive processes. Variations in spectral composition, light intensity and photoperiod can significantly influence hormonal balance, oxidative stress responses and calcium metabolism, thereby affecting growth performance, feed conversion ratio (FCR) and egg quality². In laying hens, suboptimal light spectra have been associated with impaired eggshell formation, primarily due to reduced calcium absorption and disruptions in vitamin D metabolism³. Similarly, in broiler chickens, inappropriate lighting conditions may elevate oxidative stress and corticosterone levels, adversely affecting muscle development and immune competence⁴.

Recent advancements in lighting technologies have led to the development of full-spectrum Light-emitting Diode (LED) systems. Evidence suggests that monochromatic LEDs, particularly when applied at lower intensities, can enhance broiler welfare by improving growth performance, physiological health and reducing fear-related behaviors in chickens⁵. Full-spectrum LED systems emit a broad and balanced range of wavelengths capable of stimulating photoreceptors in both the avian retina and pineal gland, thereby facilitating the regulation of circadian rhythms and improving overall physiological responses⁶. Previous studies have reported that such lighting systems can enhance calcium absorption by up to 15%, leading to improvements in bone strength and eggshell quality, while concurrently reducing the incidence of leg disorders and stress-related conditions⁷. Furthermore, improved antioxidant status under full-spectrum lighting has been demonstrated by reductions in malondialdehyde (MDA) levels and modulation of catalase activity, indicating decreased oxidative stress in poultry⁸.

In this context, the evaluation of PhysLite® lighting systems in broiler production under closed housing conditions

is of considerable importance. Investigating its effects on key physiological parameters, including stress hormone regulation, antioxidant enzyme activity and growth performance, may provide valuable insights into its potential to enhance both productivity and animal welfare. Such assessments are particularly relevant for optimizing sustainable poultry production systems in tropical environments, including regions such as Indonesia.

MATERIALS AND METHODS

Research design and experimental animals: This study was conducted to evaluate the physiological responses and growth performance of broiler chickens reared under two distinct lighting systems, conventional LED lighting and full-spectrum tetrachromatic LED PhysLite® lighting. A total of 60 day-old broiler chicks, exhibiting uniform health status and initial body weights ranging from 0.053 to 0.055 kg, were utilized. The birds were randomly allocated into two experimental groups, each comprising 30 individuals. The control group was maintained under standard white LED lighting, whereas the treatment group was exposed to full-spectrum PhysLite® LED lighting.

Housing conditions: Both experimental groups were housed separately in closed pens under standardized environmental conditions, including temperature maintained at 28-30°C, relative humidity of 60-70% and adequate ventilation. Feed and water were provided *ad libitum* throughout the study period. The experiment spanned 30 days, during which individual body weights were recorded daily from day 1 to day 30 using a digital weighing scale with a precision of 0.1 kg to monitor growth performance.

Lighting arrangement: The treatment group was subjected to a PhysLite® tetrachromatic full-spectrum LED lighting system, with controlled adjustments in light intensity and photoperiod corresponding to the physiological stages of broiler development. During the initial adaptation phase, from day 0 to day 1, continuous illumination (24 hrs) was provided. From day 2 to day 4, a lighting schedule of 21 hrs light and 3 hrs darkness at moderate intensity was implemented to support immune system development and organ maturation. Subsequently, from day 5 to day 30, the photoperiod was adjusted to 20 hrs light and 4 hrs darkness to facilitate optimal muscle and skeletal growth, as well as melatonin secretion. The spectral composition and intensity were dynamically regulated using the PhysLite® remote controller to ensure physiological and behavioral stability. In contrast, the control

group was maintained under conventional LED lighting with constant photoperiod and intensity throughout the experimental period.

Blood sampling and handling: On day 30, blood samples were collected from all birds between 07:00 and 08:00 a.m. via the brachial vein using sterile 3 mL syringes (Onemed®). The samples were immediately centrifuged at 3,000 rpm for 10 min to obtain serum, which was subsequently stored at -20°C until further biochemical analysis.

Biochemical analysis using enzymatic colorimetry: Serum corticosterone levels, along with the activities of antioxidant enzymes including superoxide dismutase (SOD) and catalase (CAT) and the concentration of malondialdehyde (MDA), were determined using enzymatic colorimetric assays. Standard biochemical protocols were followed, employing specific colorimetric reactions to quantify enzyme activities and oxidative stress markers. Absorbance was measured using a UV-Vis spectrophotometer at parameter-specific wavelengths and the results were expressed in appropriate units based on calibration standards.

Data analysis: All data were expressed as Mean $\pm$ standard deviation (SD). Statistical analysis was performed using one-way analysis of variance (ANOVA) with SPSS software (version 27.0; IBM Corp., Armonk, NY, USA) to assess

differences between control and treatment groups. Results were also presented as Mean $\pm$ standard error where appropriate and statistical significance was established at $p < 0.05$.

RESULTS

Body weight gain: Body weight gain of broiler chickens differed significantly between the control group (standard LED lighting) and the treatment group (tetrachromatic full-spectrum LED PhysLite®). By day 12, birds in the PhysLite® group (0.356 kg) exhibited a higher body weight compared to those in the control group (0.347 kg) and this difference became progressively more pronounced toward day 30. The mean final body weight at day 30 was 1.829 kg in the PhysLite® group and 1.706 kg in the control group, indicating a more consistent and enhanced growth performance in birds exposed to full-spectrum lighting (Fig. 1).

Corticosterone hormone levels: Serum corticosterone concentrations were significantly lower in the PhysLite® group (4.058 ± 0.129 ng/mL) compared to the control group (8.442 ± 0.164 ng/mL). Although, both values remained within the normal physiological range (2-10 ng/mL), the reduced levels observed in the treatment group suggest a diminished physiological stress response in broiler chickens exposed to tetrachromatic full-spectrum lighting (Fig. 2).

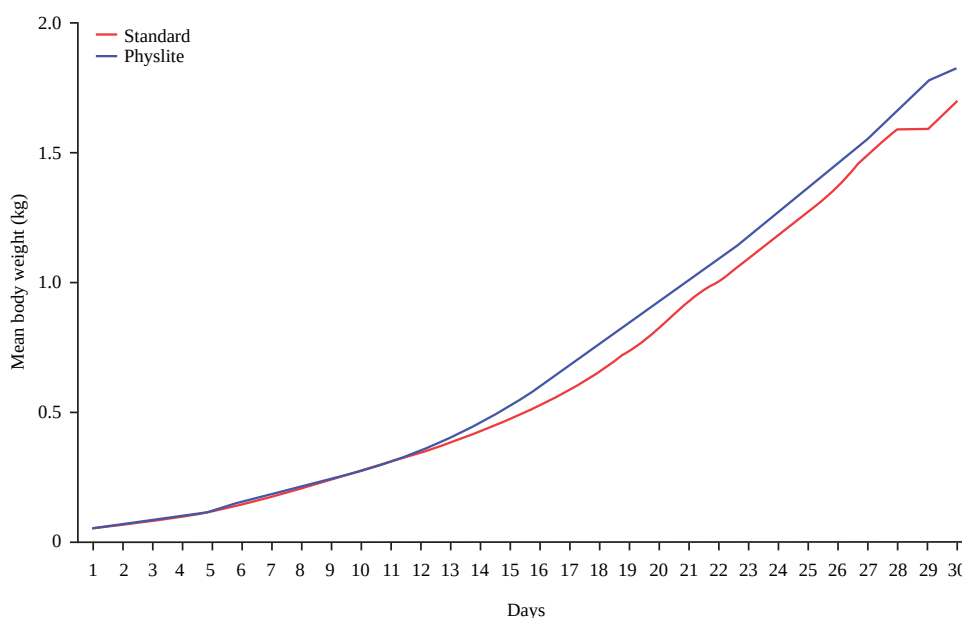


Fig. 1: Growth curve of broiler body weight

Antioxidant enzyme activity: The activity of superoxide dismutase (SOD) was higher in the PhysLite® group (4.027 ± 0.041 ng/mL) than in the control group (3.563 ± 0.030 ng/mL), indicating an enhancement of the endogenous antioxidant defense system. In contrast, catalase (CAT) activity was lower in the PhysLite® group (27.641 ± 0.921 U/L) compared to the control group (48.980 ± 2.684 U/L). This reduction suggests that broiler chickens exposed to full-spectrum lighting experienced lower oxidative stress, thereby reducing the requirement for elevated enzymatic antioxidant activity (Fig. 3).

Malondialdehyde (MDA) levels: Malondialdehyde (MDA) levels, a key indicator of lipid peroxidation, were lower in the PhysLite® group (3.406 ± 0.077 μ M) compared to the control group (4.067 ± 0.143 μ M). These results indicate that birds reared under full-spectrum lighting conditions experienced reduced lipid peroxidation and improved cellular membrane integrity, reflecting decreased oxidative damage under PhysLite® environmental conditions (Fig. 4).

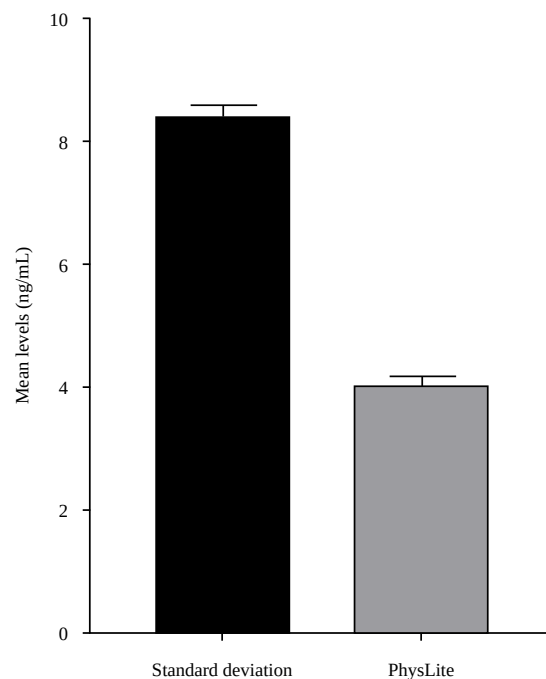
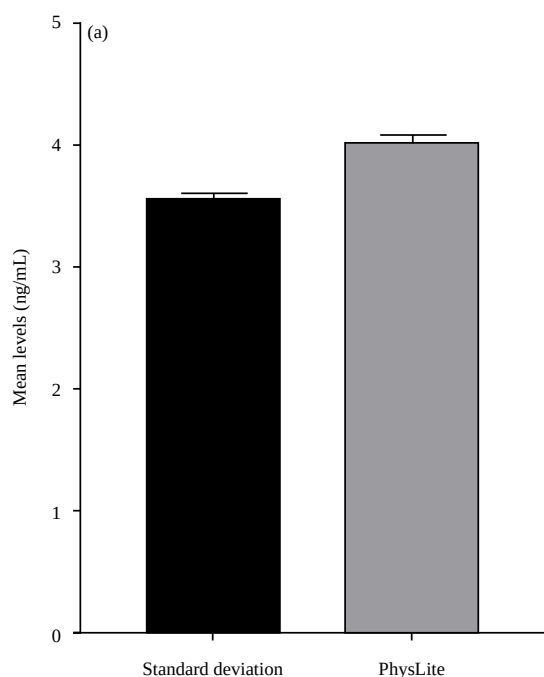


Fig. 2: Corticosterone levels

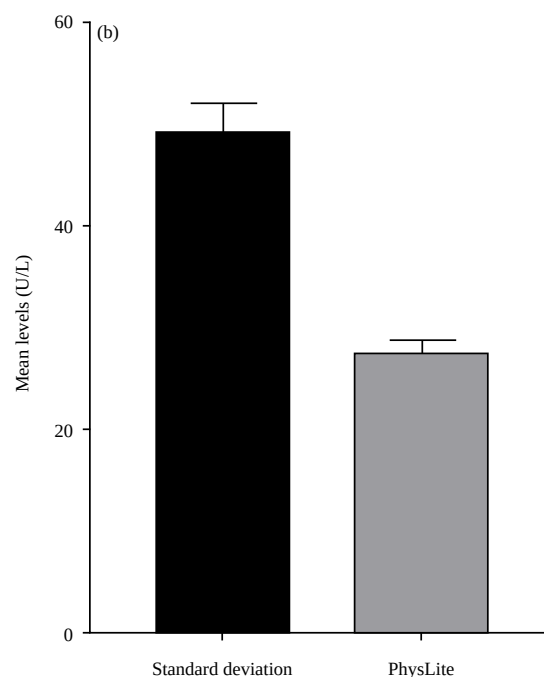


Fig. 3: Antioxidant enzyme levels, (a) Superoxide dismutase (SOD) and (b) Catalase enzyme (CAT)

DISCUSSION

The greater body weight observed in broilers exposed to full-spectrum tetrachromatic lighting indicates that light spectral composition is a critical determinant of growth efficiency. The PhysLite® full-spectrum system more closely

replicates natural sunlight, thereby facilitating optimal regulation of circadian rhythms, feeding behaviour and feed conversion efficiency. Previous studies have demonstrated that full-spectrum lighting enhances endocrine function, stimulates growth hormone secretion and improves energy metabolism in broiler chickens⁴.

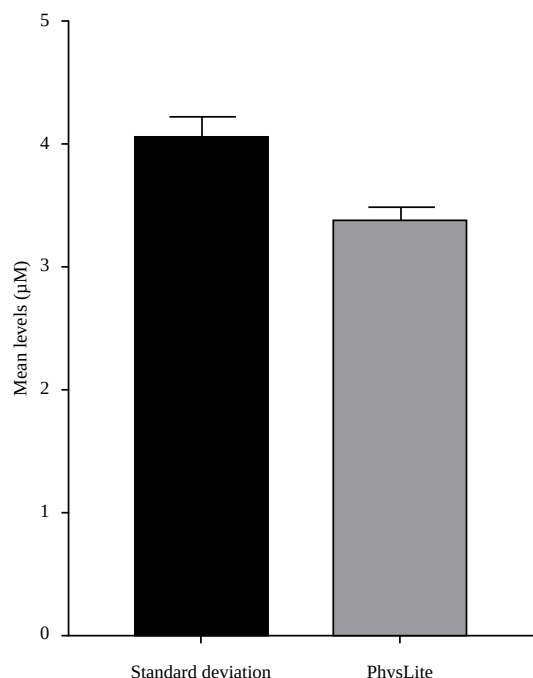


Fig. 4: Malondialdehyde (MDA) enzyme activity levels

Beyond growth performance, the application of tetrachromatic PhysLite® lighting appears to support animal welfare, as it is designed to align with the natural tetrachromatic visual system of chickens. Lighting systems incorporating blue, green and red light-emitting diodes (LEDs), commonly described as tetrachromatic illumination, have been reported to improve growth efficiency and physiological performance in poultry⁹. This approach is hypothesized to enhance welfare by more closely matching the avian visual spectrum and photoreceptor sensitivity. However, empirical evidence supporting its welfare benefits, particularly regarding consistent modulation of stress-associated endocrine markers and quantifiable behavioural responses, remains limited, with most available studies providing preliminary or inconclusive findings¹⁰.

In addition to spectral composition, the inclusion of an adequate dark period plays a fundamental physiological role through the regulation of melatonin secretion, a hormone synthesized by the pineal gland during darkness¹¹. Melatonin contributes to circadian rhythm synchronization, supports immune competence and functions as a potent antioxidant¹². In laying hens, appropriate light-dark cycles have been associated with improved reproductive performance via modulation of the hypothalamic-pituitary-gonadal (HPG) axis, leading to increased secretion of Follicle-stimulating Hormone (FSH) and Luteinizing Hormone (LH), both of which are essential for ovulation and egg production¹³. Similarly,

provision of sufficient darkness in broilers facilitates physiological recovery and melatonin-mediated antioxidant protection, thereby supporting both welfare and growth outcomes¹⁴.

The observed reduction in corticosterone concentrations in the PhysLite group suggests a diminished physiological stress response. Corticosterone is a primary biomarker of stress in poultry, with elevated levels commonly associated with environmental challenges such as heat stress, high stocking density, or inappropriate lighting conditions¹⁵. Full-spectrum lighting may contribute to stabilization of circadian rhythms and improved environmental comfort, thereby attenuating excessive activation of the hypothalamic-pituitary-adrenal (HPA) axis¹⁶.

The increase in superoxide dismutase (SOD) activity, accompanied by a decrease in catalase (CAT) activity, indicates a more efficient antioxidant defence mechanism. Superoxide dismutase constitutes the first line of enzymatic defence against superoxide radicals, whereas elevated catalase activity is generally indicative of increased oxidative burden¹⁷. Under improved environmental conditions, antioxidant homeostasis is maintained, as reflected by reduced CAT activity in the PhysLite group. These findings are consistent with previous reports demonstrating that optimized housing conditions can mitigate oxidative stress in poultry¹⁸.

Furthermore, the reduction in malondialdehyde (MDA) concentrations supports the conclusion that lipid peroxidation and associated cellular membrane damage were lower in birds exposed to PhysLite lighting. Malondialdehyde, a terminal product of lipid peroxidation, is widely recognized as a reliable biomarker of chronic oxidative stress¹⁹. A visually appropriate and welfare-oriented environment, particularly lighting that corresponds to the avian tetrachromatic visual spectrum, has been shown to reduce the generation of Reactive Oxygen Species (ROS) and preserve cellular membrane integrity²⁰.

Collectively, these findings indicate that the PhysLite® tetrachromatic full-spectrum lighting system not only enhances growth performance and physiological function but also promotes animal welfare by reducing both physiological and oxidative stress. This effect is likely mediated through improved visual comfort and closer approximation to natural light conditions. Consequently, such lighting strategies represent a promising and sustainable environmental management approach for optimizing productivity and welfare in modern broiler production systems.

CONCLUSION

The present study demonstrates that the application of PhysLite® tetrachromatic full-spectrum LED lighting significantly improves broiler performance and physiological

homeostasis. Birds reared under full-spectrum illumination exhibited greater body weight gain, reduced corticosterone concentrations and enhanced antioxidant status, collectively indicating attenuation of both physiological and oxidative stress. Alignment of the lighting environment with the natural tetrachromatic visual capacity of chickens appears to contribute to improved growth efficiency while simultaneously supporting animal welfare through reduced visual strain and more stable behavioural responses. Moreover, the observed decrease in malondialdehyde concentrations suggests enhanced cellular integrity and metabolic stability under full-spectrum conditions. In summary, PhysLite® full-spectrum lighting represents an effective, welfare-oriented environmental management strategy capable of improving productivity, health status and overall sustainability in modern broiler production systems.

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