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Role of Lighting Programs in Poultry Performance

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The poultry industry is one of the fastest-growing sectors of livestock production worldwide and plays a major role in food security and economic development, especially in India. Rapid growth in the sector has been driven by increasing population, rising demand for animal protein and the expansion of commercial poultry farming. However, modern poultry production is highly influenced by environmental factors, among which lighting management is particularly important. Light acts as a key environmental signal that regulates biological rhythms, behavior, growth and reproductive processes in birds through neuroendocrine pathways. Lighting programs in poultry production are mainly determined by three components: light intensity, photoperiod (duration of light) and light color or wavelength. Proper manipulation of these factors can improve feed intake, growth rate, egg production, feed conversion efficiency and bird welfare. Research shows that blue and green light can promote growth in broilers, while red and white light are more beneficial for reproductive performance in layers. Intermittent and well-designed lighting schedules can also enhance welfare by reducing leg disorders, improving activity and lowering mortality rates. Therefore, effective lighting management is an essential tool for optimizing productivity, health and welfare in modern poultry production systems.

Introduction

The poultry industry is considered the fastest-growing segment of the global livestock sector and it has been recognized as one of the most rapidly expanding components of agriculture both worldwide and in India. Research by S. Persaud *et al.*, 2012 identified poultry meat as the fastest-growing component of global meat demand. This rapid expansion is largely driven by the increasing global population, which is projected to reach approximately 9.5 billion by 2050, along with changing consumer dietary preferences that increasingly favor animal-based protein sources (I. Augustine *et al*., 2015).

In India, the poultry sector has experienced a remarkable transformation over the last four decades, evolving from small-scale backyard farming to a large and highly commercialized agribusiness industry (R. Chatterjee *et al.*, 2015). This structural shift has positioned India among the leading poultry-producing countries in the world, ranking as the fourth-largest producer of eggs and the fifth-largest producer of broiler meat (S. Saran *et al.*, 2005). The sector also plays a significant role in the national economy. According to Mohd Mujahed Ali *et al.*, 2015, the domestic poultry market is valued at approximately Rs 49,000 crore and has been expanding at an annual rate of about 20%, with production levels reaching nearly 3.2 million tons of broiler meat and 2.86 million tons of eggs. Furthermore, J. S. Toor *et al.*, 2022 reported that the growth rate of poultry farming in India is nearly five times higher than that of conventional agricultural crop production.

Consistent expansion in production indicators further highlights the rapid growth of this sector. Studies by R. Chatterjee *et al.*, 2015 documented annual growth rates of approximately 4–6% in egg production and 8–10% in broiler production. As a result, the per capita availability of poultry products in India has increased to around 60 eggs and 2.5 kg of poultry meat per person annually. Beyond its economic contribution, the poultry industry also plays a vital role in ensuring food security and reducing poverty. U. Pica-Ciamarra *et al.*, 2010 emphasized that poultry production provides an affordable source of high-quality animal protein, particularly benefiting low-income populations in both rural and urban areas. The sector also contributes to overall agricultural development in India, where agriculture supports nearly 58% of the population. Looking ahead, J. Hellin *et al.*, 2015 projected that India will continue to strengthen its position in global poultry trade, particularly through exports to Middle Eastern markets, supported by competitive pricing and strong entrepreneurial activity within the sector.

Despite its rapid expansion, poultry production is highly influenced by environmental conditions. Environmental fluctuations associated with climate change have raised serious concerns regarding poultry health, welfare and productivity. K. El-Sabrout *et al.*, 2022 reported that environmental stressors can adversely affect physiological processes and production performance in poultry. Similarly, C. Ncho *et al.*, 2024 demonstrated that various abiotic stress factors can trigger physiological responses in birds, ranging from mild stress to severe health complications and even mortality. Prolonged exposure to such stressors may lead to the accumulation of reactive oxygen species, resulting in oxidative stress, impaired reproductive performance and weakened immune function. Furthermore, the structural intensification of poultry production systems has increased environmental challenges throughout the poultry value chain.

Among the various environmental management factors, lighting management plays a particularly critical role in poultry production. Light acts as a powerful environmental cue that regulates biological rhythms and physiological processes in birds. Yufei Huang *et al.*, 2026 demonstrated that light functions as a potent *zeitgeber*, synchronizing circadian rhythms and regulating neuroendocrine signaling pathways that are essential for maintaining bird health, welfare and productivity. Extensive research over the past five decades has explored the role of artificial lighting in improving growth performance and egg production while maintaining efficient feed conversion ratios (S. S. Nissa *et al.*, 2023). In addition, Prasanna Pal *et al.*, 2019 reported that proper light management can effectively influence feed intake, feed efficiency, egg hatchability, carcass yield and certain disease-related traits.

Lighting programs in poultry production are generally determined by three fundamental parameters: light intensity, photoperiod (lighting duration) and wavelength or color of light. Light intensity, which refers to the brightness of illumination, varies according to the production stage. Recommended light intensity is higher during the chick stage and is gradually reduced to approximately 3–5 lux during the grow-out period. Photoperiod management involves regulating the duration of light exposure to influence physiological development and reproductive performance. According to Kanaksinh Chavda *et al.*, 2025, lighting duration during the grower phase is typically maintained at around 14 hours and gradually increased by approximately 30–35 minutes per week until reaching about 16 hours for laying birds. In addition to intensity and duration, the wavelength or color of light also plays an important role in poultry performance. Research by F. Soliman *et al.*, 2020 reported that more than 50% of broiler studies observed improved body weight under blue light (450 nm) and green light (550 nm), with increases exceeding 3%. In contrast, red light (around 700 nm) was found to increase bird activity and aggressive behavior by more than 30%, which may negatively affect body weight and overall performance.

Physiology of Light Perception in Poultry

Light perception in poultry represents a complex physiological mechanism in which light functions as an important environmental regulator influencing several biological processes beyond simple vision. It regulates behavior, metabolism, growth and reproduction through intricate neuroendocrine pathways. Although the fundamental mechanisms of light perception in birds are well recognized, detailed information regarding the exact anatomical structure of the avian eye and the precise characteristics of photoreceptors located in the retina and hypothalamus is not fully described in the available literature (Yufei Huang *et al.*, 2026). Birds are highly sensitive to environmental light cues and these signals are transmitted through the nervous and endocrine systems to regulate physiological activities associated with circadian rhythms and overall productivity. One of the most important hormonal mediators involved in the physiological response to light is melatonin, commonly referred to as the "hormone of darkness." This hormone plays a central role in regulating circadian rhythms and maintaining the biological clock in poultry. The secretion of melatonin is strongly influenced by light exposure, particularly artificial light at night, which can significantly suppress melatonin production even at extremely low light intensities. Additionally, melatonin secretion shows a strong sensitivity to specific light wavelengths (M. Grubisic *et al.*, 2019). Through these mechanisms, light regulates the daily physiological rhythms of poultry by influencing hormonal signaling pathways associated with sleep–wake cycles, metabolism and immune responses.

Light-mediated regulation of melatonin also contributes to the synchronization of circadian rhythms in birds. Experimental studies have shown that exposure to blue light during the evening hours can significantly suppress melatonin secretion. For instance, a two-hour exposure to blue light in the evening has been observed to reduce melatonin levels, with the strongest suppression occurring at shorter wavelengths. However, melatonin concentrations can recover rapidly once the light stimulus is removed, often returning to normal levels within approximately fifteen minutes after the cessation of light exposure (Leena Tähkämö *et al.*, 2018). These findings highlight the sensitivity of the avian circadian system to light quality and timing.

The reproductive system in poultry is also highly responsive to light regulation. Reproductive activity in birds is primarily controlled by the hypothalamic–pituitary–gonadal axis, where the hypothalamus releases gonadotropin-releasing hormone in a pulsatile manner. This hormonal signal stimulates the secretion of other reproductive hormones that regulate ovarian activity and egg production. Research has demonstrated important relationships between light exposure, melatonin secretion and reproductive physiology. Alterations in melatonin secretion have been associated with reproductive disturbances and irregular reproductive cycles, indicating that proper light management is essential for maintaining reproductive efficiency (M. Barron *et al.*, 2007). In addition to its physiological functions, light management also acts as an important environmental enrichment strategy in poultry production systems. Appropriate light and dark schedules have been shown to improve bird welfare by promoting better physical development and behavioral stability. Studies have indicated that well-designed lighting programs can enhance leg health and overall welfare in broiler chickens, while variations in lighting intensity may influence the occurrence of contact dermatitis and affect bird mobility (I. Pedersen *et al.*, 2019). These welfare-related benefits further emphasize the importance of carefully managing lighting conditions in modern poultry housing systems.

Components of Lighting Programs

Light Intensity: Light intensity for poultry is measured in lux, with recommended levels varying significantly between broilers and layers based on production and welfare considerations. For broilers, research demonstrates a range of 5-20 lux depending on priorities: a comprehensive meta-analysis identified 5 lux as the minimum threshold to maintain productivity and welfare, with levels below this causing welfare concerns and productivity losses Yefeng Yang *et al.*, 2018, while the European Union mandates a minimum of 20 lux compared to lower intensities commonly used in the United States Douglas J. Aldridge *et al*., 2021. Studies comparing these intensities show that while 5 lux produces better feed conversion ratios Douglas J. Aldridge *et al*., 2021, 20 lux improves welfare indicators such as reduced footpad lesions A. Deep *et al*., 2010 and aligns with broiler feeding preferences M. Raccoursier *et al.*, 2019. For layers, evidence is considerably more limited, with historical research suggesting no significant production differences across a wide range of 5.38-107.64 lux W. C. Skoglund *et al.*, 1975 and reviews questioning whether the traditional 5 lux recommendation remains optimal P. Lewis *et al.*, 1999, indicating that layer lighting requirements are less well-established than those for broilers.

Photoperiod (Light Duration): Continuous lighting increases egg production in layer birds while intermittent lighting reduces feed consumption and may improve welfare, though effects vary by production stage and metric. K. Koelkebeck *et al.* (1986) studied 240 White Leghorn hens and found continuous photoperiods significantly increased hen-day egg production ($P<0.01$), while intermittent photoperiods significantly reduced feed consumption ($P<0.05$). Similarly, Ailian Geng *et al.* (2018) examined 630 laying hens and found continuous lighting produced higher egg mass during weeks 44-57, but intermittent lighting improved egg quality parameters at week 37. Welfare considerations favor intermittent lighting, as JL Campo *et al.* (2002) demonstrated that continuous near-light (23L:1D) significantly increased fear response in 36-week-old hens compared to 14L:10D cycles ($P<0.05$), while T. Morris *et al.* (2004) noted intermittent lighting saves approximately 5% feed consumption without output loss when amino acid content is adequate. The choice between lighting systems involves trade-offs between maximizing production metrics and optimizing resource efficiency and bird welfare.

Light color (Wavelength): Light wavelength significantly affects poultry performance, with blue (450 nm) and green (550 nm) light generally promoting growth while red (700 nm) and white light enhance reproductive function. More than 50% of broiler studies demonstrated that blue and green light increased body weight by over 3% compared to red light, which increased activity and aggressive behavior by over 30%, negatively affecting growth performance F. Soliman *et al.*, 2020. This growth advantage of shorter wavelengths has been consistently observed across multiple studies, with birds under blue or green light remaining calmer and showing reduced activity compared to those under red or white light D. S. Prayitno *et al.*, 1997. Conversely, for reproductive performance, red and white light proved superior, resulting in higher estradiol concentrations, lower age at first egg and improved egg production in laying hens compared to green light M. Baxter *et al.*, 2014, with red LED also enhancing sperm quality in roosters and egg production across multiple poultry species O. Oso *et al.*, 2022. The underlying mechanism involves differential photoreception pathways, where growth responses depend primarily on retinal photoreception while reproductive responses are mediated through hypothalamic light reception. However, recent large-scale commercial trials suggest these wavelength effects may be minimized when light intensity is properly equalized and balanced for avian spectral sensitivity B. Franco *et al.*, 2022.

Lighting Programs in Broiler Production

Lighting programs in broiler production play an important role in improving both performance and welfare parameters. Different lighting schedules, particularly intermittent photoperiods, have been shown to produce consistent positive effects on broiler productivity. Studies indicate that intermittent lighting programs can increase weight gain by approximately 3.4–5.8%, improve feed conversion ratio by up to 7.3%, enhance bird mobility by as much as 46.5%, and reduce mortality rates by about 0.43–0.72% (M. A. Arowolo *et al.*, 2019). These results demonstrate that properly designed lighting strategies can significantly enhance growth performance while also supporting bird health and welfare.

The growth rate and final body weight of broilers are also influenced by specific light characteristics such as wavelength and intensity. Research shows that blue and green light can increase body weight by more than 3%, whereas red light tends to stimulate bird activity but may lead to lower weight gain. In addition, variations in light intensity affect growth outcomes; higher light intensities, such as 20 lux compared with 5 lux, increase bird activity but can reduce final body weight by approximately 2.8–5.1% (J. Rault *et al.*, 2016). These findings highlight the importance of carefully balancing light intensity and color in broiler production systems to achieve optimal growth performance. Lighting conditions also have a strong influence on behavioral activity in broilers. Appropriate lighting interventions can increase the overall activity levels of birds, which is beneficial for their physical development and welfare. For example, bright red light has been shown to significantly increase behaviors such as walking, feeding and stretching, particularly when applied during the early stages of the rearing period (D. S. Prayitno *et al*., 1997). Similarly, higher light intensities, such as 180 lux compared with 6 lux, have been found to significantly increase standing, walking and general activity levels among broilers (R. C. Newberry *et al.*, 1988).

Lighting programs are also critically important for improving broiler welfare by reducing leg disorders and stress-related problems. Intermittent lighting schedules have been reported to lower the incidence of leg problems from approximately 20% to about 6–10% without negatively affecting production performance (J. Renden *et al.*, 1996). In addition, bright red light has been shown to reduce gait abnormalities when compared with continuous dim blue lighting (D. S. Prayitno *et al.*, 1997). Higher light intensities have also been associated with reductions in leg disorders and carcass bruising (R. C. Newberry *et al.*, 1988). Furthermore, increasing light intensity has been found to linearly reduce the occurrence of ulcerative footpad lesions in broilers (A. Deep *et al.*, 2010). Management strategies that modify lighting conditions to slow early growth rates can further help alleviate several welfare problems commonly associated with the rapid growth of modern broiler strains (W. Bessei *et al*., 2006).

Lighting Programs in Layer Production

Lighting programs represent a critical management tool in layer production with documented effects across multiple performance parameters. Light serves as the primary environmental cue for reproductive hormone release, though it is not essential for sexual maturity since birds can commence ovulation in darkness Imtd Jácome *et al.*, 2014. Photoperiod length directly regulates age at sexual maturity, with longer photoperiods advancing and shorter programs delaying first egg production W. I. Muir *et al.*, 2024. Step-down lighting programs during pullet rearing effectively delay sexual maturity by extending bone growth plate closure, allowing for improved skeletal frame development. However, this skeletal benefit does not translate to improved bone mineralization at end of lay P. Hester *et al.*, 2011. Early research established that constant 24-hour lighting during growing periods inhibits sexual maturity onset and reduces laying intensity J. R. Carson *et al.*, 1958.

Layers require photostimulation with more than 12 hours of light regardless of the specific artificial lighting program applied. Lighting program design significantly impacts production rates, as demonstrated by comparisons between the North Carolina program (24-hour light pre-fast followed by 12 hours daily) and Washington program (8-hour photoperiod), where the former increased post-molt egg production D. K. Andrews *et al.*, 1987. Intermittent lighting programs provide viable alternatives for open-sided housing systems commonly used in tropical regions. Egg size responds positively to specific lighting manipulations. Ahemeral light-dark cycles of 26-28 hours significantly increased the percentage of large eggs (≥56g) at 25-29 weeks of age compared to standard 24-hour cycles R. Fitzsimmons *et al.*, 1991. Pullets reared under longer photoperiods with ad libitum feeding produced heavier eggs during early lay. Delaying photostimulation from 20 to 24 weeks increased mean egg weight but reduced total egg numbers M. Ciacciariello *et al.*, 2005.

Artificial lighting programs demonstrate limited influence on egg quality parameters, with no significant effects on internal quality measures. Shell weight and specific gravity remain unaffected by lighting treatments. However, transcranial light reception represents the most important pathway for reproductive stimulation in poultry Imtd Jácome *et al.*, 2014. Molting and laying cycle control through lighting programs shows complex interactions with nutritional management. The effectiveness of different lighting programs during induced molt depends on concurrent dietary treatments, with significant lighting-by-molt diet interactions affecting performance outcomes. Feed conversion efficiency improved under the North Carolina lighting program during molt recovery D. K. Andrews *et al.*, 1987.

Conclusion

Lighting programs play a crucial role in improving productivity, health and welfare in poultry production. Proper control of light intensity, duration and wavelength can influence growth performance, feed efficiency, reproductive activity and bird behavior. Scientific studies have shown that well-planned lighting strategies can increase body weight, improve egg production, reduce mortality and enhance overall bird welfare. In broilers, lighting programs help regulate growth rate and reduce leg disorders, while in layers they are essential for controlling sexual maturity and maintaining consistent egg production. As poultry production systems continue to intensify, effective lighting management becomes increasingly important for maintaining both productivity and animal welfare. Therefore, adopting scientifically designed lighting programs can help farmers achieve better performance, improve economic returns and support sustainable poultry production.

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