Performance of Hens exposed to varying lighting colours and intensities at the early and mid-laying phases

[1]Olanrewaju, A. I., [2]Osaiyuwu, H. O., [1]Oludoyi, I. A., [1]Odu, O., [1]Adebiyi, F. G., [1]Folayan, B. E., [1]Ibikunle, O. A., [1]Oyedele, A. K., [1]Ajao, S. O., [1]Arowolo, S. T., and *[1]Ogunwole, O. A.

[1]Agricultural Biochemistry and Nutrition Unit, Department of Animal Science, University of Ibadan, Ibadan, Nigeria.

[2]Animal Breeding and Genetics Unit, Department of Animal Science, University of Ibadan, Ibadan, Nigeria.

***Corresponding author:** oa.ogunwole@ui.edu.ng

Abstract

*Lighting is an important environmental factor affecting laying hen reproduction and performance, yet optimal colour-intensity combinations remain underexplored in tropical climates, such as Nigeria. Implications of lighting colour and intensity on performance of laying hens in early and mid-laying phases were assessed in this study. ISA Brown pullets (n=390), aged 16 weeks, were randomly allotted to four lighting colours (Blue, Green, Red, and White) and three intensities (9.0, 13.5, and 18.0 lux) in a (4×3)+1 augmented factorial arrangement (the hens received an extra four hours of artificial lighting (6:30-10:30 p.m.) in a completely randomised design. Each treatment had five replicates (6 hens/replicate; 3 birds/cell, 2 cells/replicate). Parameters including egg production, feed intake, egg mass and FCR were monitored daily/weekly. Data were analysed using descriptive statistics and ANOVA, with means separated at $\alpha_{0.05}$. Control HDEP was lowest (61.4% early, 63.0% mid-phase) vs. treatments (78-80%). Interaction of lighting colour and intensity on FCR showed that hens in the control treatment had significantly higher ($p>0.05$) FCR than T2 (blue colour * 9 lux), but was similar to other treatment groups. For the interaction of lighting colour and intensity at the mid-laying phase, hens on control had least HDEP of 63.0%, than hens in other treatment groups. Hen under green lighting started laying at week 18 and peaked in week 22 at 89%, thereafter maintained relatively consistently stable HDEP throughout the phase. Also, hens exposed to 9.0 lux started laying at weeks 18 and peaked in 22 weeks at 85%, had higher HDEP ($p<0.05$) in the laying periods. The control group with lower HDEP than other colours and intensities, peaked at week 22. Therefore, appropriate lighting colour and intensity were considered important for enhancing laying hen performance.*

Keywords: lighting colour, lighting Intensity, hen-day egg production, ISA Brown, point and peak of lay.

Performance de poules exposées à différentes couleurs et intensités d'éclairage aux phases de début et de mi-ponte

Résumé

L'éclairage est un facteur environnemental important affectant la reproduction et les performances des poules pondeuses, mais les combinaisons optimales couleur-intensité restent sous-explorées dans les climats tropicaux, comme au Nigeria. Les implications de la couleur et de l'intensité de l'éclairage sur les performances des poules pondeuses en début et mi-ponte ont été évaluées dans cette étude. Des poulettes ISA Brown (n=390), âgées de 16 semaines, ont été réparties aléatoirement selon quatre couleurs d'éclairage (Bleu, Vert, Rouge et Blanc) et trois intensités

*(9,0, 13,5 et 18,0 lux) dans un dispositif factoriel augmenté (4×3)+1 (les poules ont reçu quatre heures supplémentaires d'éclairage artificiel (18h30-22h30) selon un plan complètement randomisé). Chaque traitement comportait cinq répétitions (6 poules/répétition ; 3 oiseaux/cage, 2 cages/répétition). Des paramètres tels que la production d'œufs, la consommation d'aliments, la masse d'œufs et l'indice de consommation ont été surveillés quotidiennement/hebdomadairement. Les données ont été analysées à l'aide de statistiques descriptives et d'une ANOVA, avec séparation des moyennes à a=0,05. Le contrôle a montré le Ponde journalière par poule (PJpP) le plus faible (61,4 % en début, 63,0 % en mi-phase) comparé aux traitements (78-80 %). L'interaction couleur-intensité sur l'indice de consommation a montré que les poules du traitement témoin avaient un indice de consommation significativement plus élevé (p>0,05) que le traitement T2 (couleur bleue * 9 lux), mais était similaire aux autres groupes. Pour l'interaction couleur-intensité en mi-phase de ponte, les poules témoins avaient le PJpP le plus bas (63,0 %) comparé aux autres groupes. Les poules sous éclairage vert ont commencé à pondre à la semaine 18 et ont atteint un pic à la semaine 22 à 89 %, maintenant ensuite un PJpP relativement stable tout au long de la phase. De plus, les poules exposées à 9,0 lux ont commencé à pondre à 18 semaines et ont atteint un pic à 22 semaines à 85 %, avec un PJpP plus élevé (p<0,05) durant les périodes de ponte. Le groupe témoin, avec un PJpP inférieur à celui des autres couleurs et intensités, a atteint son pic à 22 semaines. Par conséquent, une couleur et une intensité d'éclairage appropriées ont été considérées comme importantes pour améliorer les performances des poules pondeuses.*

Mots-clés: couleur d'éclairage, intensité d'éclairage, ponde journalière par poule, ISA Brown, début et pic de ponte.

Introduction

Lighting is one of the significant environmental factors that affect feeding, resting, aggression, and egg-laying behaviour, egg production and quality, and laying hens' health (Svobodova *et al*., 2015). Artificial lighting is widely used in contemporary poultry pens to improve the reproductive performance of laying hens (Kosin *et al*., 2024). The physiological impact of light is achieved when it is detected by the eye and converted to nerve impulses, which will be transmitted to the brain (Rozenboim *et al*., 2022).

Light activates the gonadal cycle to induce the onset of lay by stimulating the nerve centre area via the eyes to cause the release of gonadotropin-releasing hormone (Liu *et al*., 2025). This causes the anterior pituitary gland to release follicle-stimulating hormone (FSH) and luteinizing hormone (LH), required for follicular growth and ovulation (Cheng *et al*., 2021). Lighting triggers sexual hormones secretion, which are responsible for the production of essential sex steroid hormones, such as testosterone, oestrogen, and progesterone (Ahmad *et al*., 2023).

Research studies on the impacts of light sources on performance, behaviour, and reproductive traits of chickens have been documented (Khaliq *et al*., 2018, Al-hsenawi *et al*., 2020, Zaguri *et al*., 2020). For instance, green light advanced onset of lay (Khaliq *et al*., 2018), while 9-18 lux of lighting intensity improved HDEP by 10-20% (Al-Hsenawi *et al*., 2020, Zaguri *et al*., 2020). Proper lighting conditions are important for the development and normal functioning of the reproductive system and the overall development of laying hens (Patel *et al*., 2016). Therefore, the proprietary of artificial lighting with different durations, colours, and intensities is now devised for use in poultry production to increase performance and productivity of laying chicken (Lee *et al*., 2025).

However, there is a lack of information on the implications of lighting colour and its combination with lighting intensity for laying birds in the Nigerian poultry industry. Thus, this study was aimed at assessing the implications of varying lighting colours and intensities on the performance of laying hens across the early and mid-laying phases.

Materials and Methods

Experimental Site

The experiment was conducted at the Poultry Unit, Teaching and Research Farm, University of Ibadan, Ibadan, Nigeria, which lies between longitudes 7°27.05N and 3°53.74 of the Greenwich Meridian East, at an altitude of 200m above sea level. The average temperature and relative humidity of the location are between 23-42°C and 60-90%, respectively.

Project Design, Experimental Protocols and Animal Management

ISA Brown pullets (n=390), with proven records of medication and vaccination schedule, at week 16, were used for this study. The pullets were raised in a conventional cage house, with each cell (3 birds per cell; 2 cells make a replicate) in the three-tier cage measuring 40 × 41 × 32 cm. The study was carried out at the early (week 18-30) and mid (week 31-50) laying phases of the hens. The pullets were allotted to varying lighting colours (blue, green, red, and white) and intensities (9, 13.5, and 18 lux), for an additional four hours daily (6:30-10:30 p.m. daily), while those on the control group were exposed to the natural photoperiod. The design of the experiment was a (4×3) +1 factorial experiment in a completely randomised design. Each treatment was replicated five times, with each replicate containing six hens, at three birds per replicate (two cells represent one replicate). The experimental birds were offered isonitrogenous (16.00% crude protein) and isocaloric (2600kcal/kg Metabolisable energy) diets for the duration of the study. Routine care and experimental protocols used were approved by the Department of Animal Science, University of Ibadan, Ibadan, Nigeria, and conformed to published guidelines for the ethical conduct and reporting of animal research (Jarvis *et al*., 2005; Kilkenny *et al*., 2010).

Data Collection

Pullets were weighed just after their arrival. Feed intake (g) and feed conversion ratio (FCR) were calculated weekly as indicated by the formulae below:

Feed intake/bird = <u>Feed offered – Leftover</u>

Feed Conversion Ratio = <u>Feed Intake (g)/week</u>

Egg mass (g)/week

$$\text{Egg Mass} = \frac{\text{Average egg weight}}{\text{HDEP}}$$

The egg production was recorded daily, and the hen-day egg production (HDEP) was calculated daily for each treatment using the formula below:

$$\text{HDEP} = \frac{\text{Total eggs laid per treatment}}{\text{Number of hens in treatment}} \times 10$$

Statistical Analysis

Data were subjected to descriptive statistics and analysis of variance using SAS (2009), and means were separated with the Duncan's Multiple Range Test option of the same software at $\alpha_{0.05}$.

Results and Discussion

The hen-day egg production of hens exposed to varying lighting colours is presented in Fig. 1. Hens exposed to the green colour reached the point of lay (week 18) earlier than hens raised under the other colours and control. Also, they reached the peak of lay (week 22 and 87%) earlier than other colours, maintaining a consistently high HDEP over time. This suggests that lighting colour influences the hypothalamic-pituitary-gonadal (HPG) axis of laying hens. Hens have photoreceptors in the hypothalamus, pineal gland, and retina, which detect different lighting colours and regulate hormonal responses that control egg production (Yoshimura and Ebihara, 2014). Light penetrates the skull and stimulates the deep-brain photoreceptors (DBP) to trigger the release of gonadotropin-releasing hormone (GnRH) from the hypothalamus (Kuenzel *et al*., 2015). GnRH then stimulates the anterior pituitary gland to release FSH and LH, which are the hormones that promote ovarian follicle development, trigger ovulation, and regulate oestrogen production (Johnson, 2015). Previous studies (Baxter *et al*., 2014) have asserted that lighting colour is effective in stimulating the reproductive axis in laying chicken, resulting to an increase in GnRH secretion and subsequent hormonal cascades that improve egg production, aligning with the findings in this study

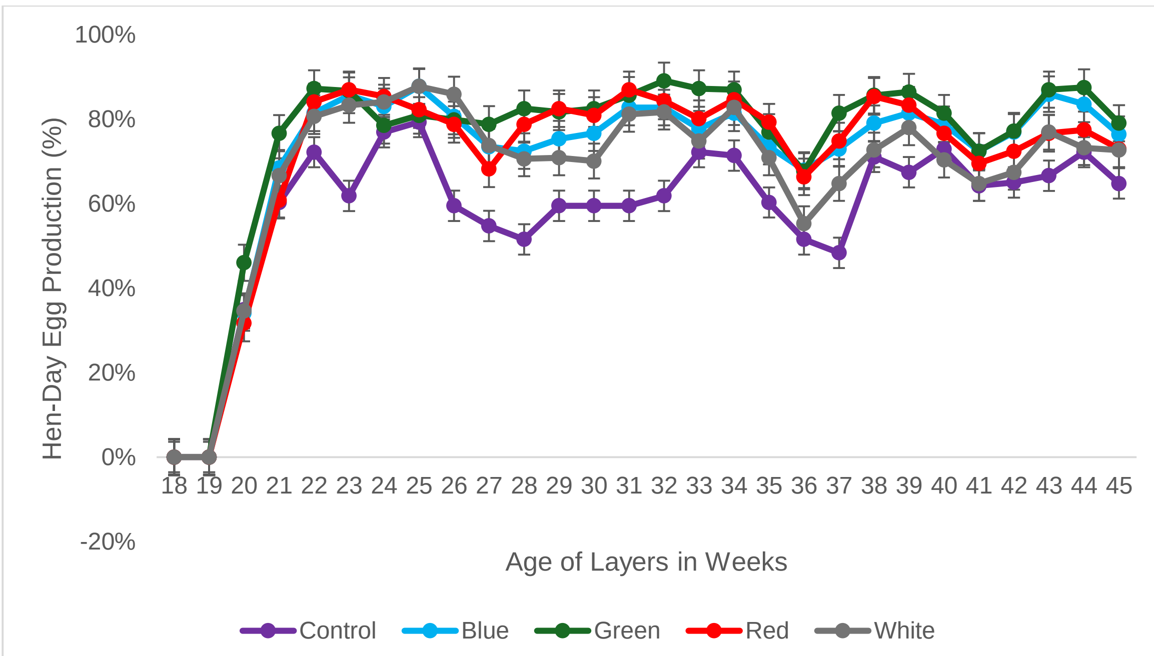

Figure 1: Hen-Day Egg Production of Hens Exposed to Varying Lighting Colours

The hen-day egg production of hens exposed to varying lighting intensities is presented in Fig. 2. Hens exposed to 9 lux of lighting intensity reached the point of lay (week 18) earlier than hens raised under the control treatment and other light intensities. Also, they reached the peak of lay (week 22 and 85%) earlier than other intensities, maintaining a consistently high HDEP over time. The lower lighting intensity of 9.0 lux has been linked to increased feed consumption, ensuring sufficient nutrient availability for sustained egg production (Li *et al*., 2016). These findings align with previous research (Çavuşoğlu and Petek, 2021) indicating that reduced light intensities promote higher feed intake, thereby improving overall egg production performance. Unlike Avuolu and Petek (2021), feed intake showed no intensity effect (Table 2; p>0.05), which could be due to isocaloric diets sabilising intake or tropical ambient temperatures overriding photostimulation.

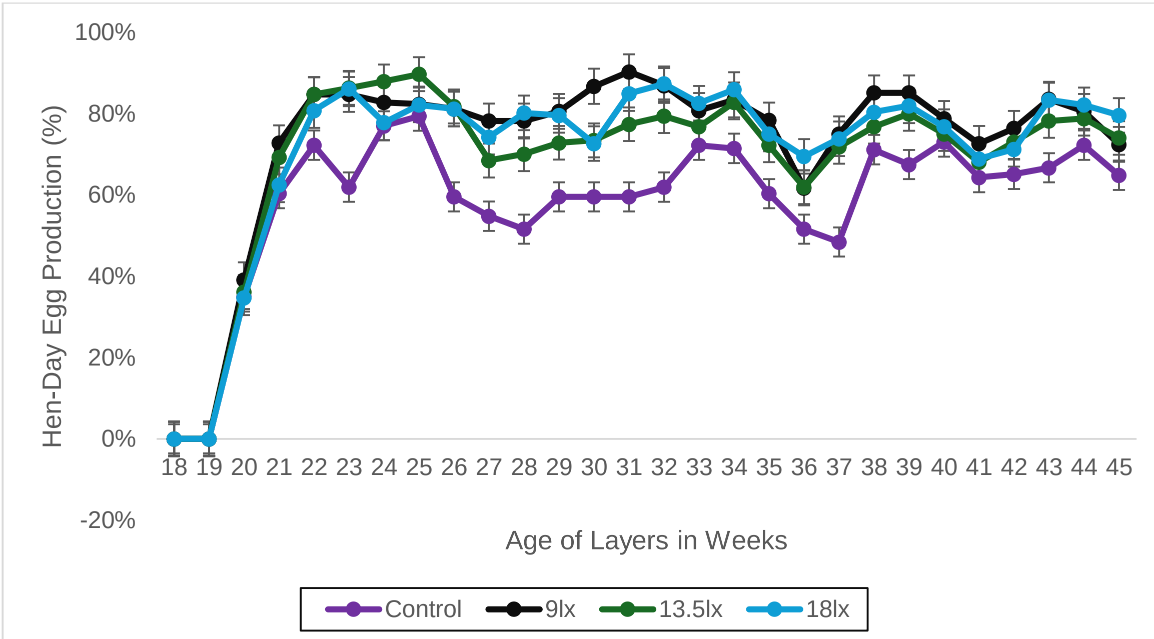

Figure 2: Hen-Day Egg Production of Hens Exposed to Varying Lighting Intensity

The regression analysis of hen-day egg production (HDEP) in response to varying lighting intensities is presented in Fig 3. Hen-day egg production profile under different lighting intensities shows how photoperiodic and neuroendocrine mechanisms modulates the performance of hens. The control group experienced reduced and irregular HDEP, which may be because of insufficient stimulation of the hypothalamic photoreceptors. This leads to inhibited gonadotropin release and elevated melatonin levels that inhibit reproduction (Derese *et al*., 2024). Hens on 9 lux of lighting intensity yielded the highest HDEP, suggesting that this intensity gave the best balance between photostimulation and physiological comfort. Moderate lighting intensity is sufficient to stimulate the hypothalamic and retinal photoreceptors, thereby improving gonadotrophin-releasing hormone (GnRH), LH, and FSH secretion, follicular growth and development, and ovulation (Baxter *et al*., 2014). At 13.5 lux, a consistent and high hen-day egg production (HDEP) profile was evident. This is likely to be perfect for successful oestrogen synthesis and vitellogenin transport to enable continuous egg production and may trigger normal oviposition and feeding activities (Morbarkey *et al*., 2010). The 18-lux group was very predictable in HDEP, which shows good photoperiodic entrainment. While having lesser output than hens on 9 lux, good egg production is still maintained, due to greater pineal synchronisation and stable neuroendocrine activity (Lewis *et al*., 2007). However, lighting beyond 15-20 lux can lead to more behavioural stress in the long run (Kristensen *et al*., 2007).

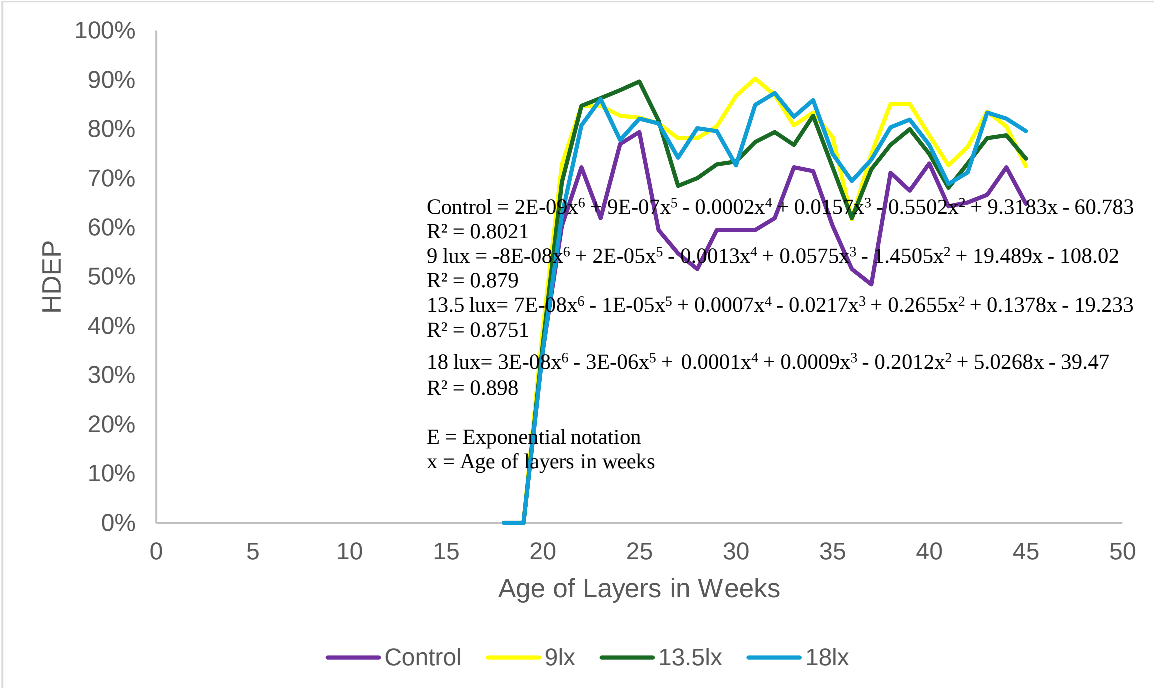

Fig. 3: Hen-Day Egg Production of Hens as Influenced by Lighting Intensity at the Early and Mid-Laying Phases

Figure 4 presents the regression analysis of hen-day egg production under green lighting at varying intensities. Among tested intensities, green light at 9.0 lux (G9.0) produced the highest and most stable HDEP throughout both early and mid-laying phases. Although higher intensities of 13.5 and 18.0 lux under green light produced strong early responses, they were followed by fluctuations at the mid-laying phase. Conversely, green light at 9.0 lux showed not only the earliest peak in production but also sustained performance with minimal volatility during the laying phases. This implies that low to moderate-intensity green light provides sufficient photostimulation for early sexual maturation while minimising endocrine and oxidative stress. Green light, particularly within the 500-570nm range, has been shown to effectively stimulate retinal and hypothalamic photoreceptors, resulting in improved gonadotrophin-releasing hormone (GnRH) secretion and ovarian development (Barros *et al*., 2024). However, excessive lighting intensity can increase the metabolic rate and oxidative load, potentially disrupting folliculogenesis and long-term egg production (Yang *et al*., 2016a). The stable performance under G9.0 reflects an optimal balance between reproductive stimulation and physiological stability (Yang *et al*., 2016b). Previous research (Reddy *et al*., 2020) ascertained that lighting wavelength and intensity significantly improve the egg-laying performance of hens.

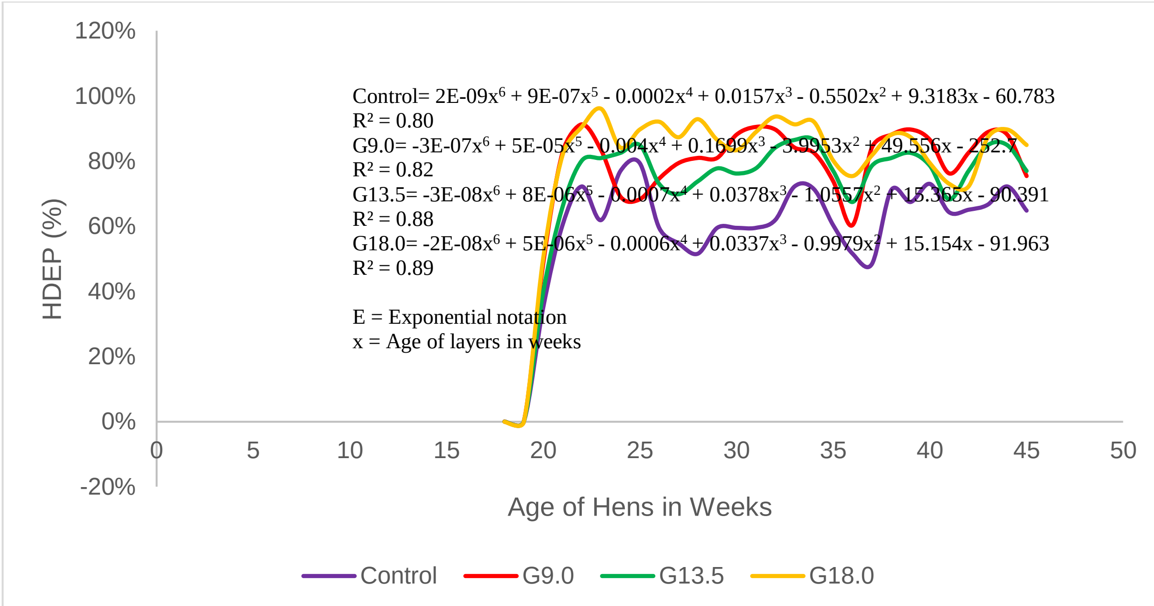

Fig 4: Hen-Day Egg Production of Hens as Influenced by Green Lighting at the Early and Mid-Laying Phases

The effect of interaction of lighting colour and intensity on the performance of hens at the early laying phase is shown in Table 1. The feed intake of laying hens was not significantly influenced ($p>0.05$) by the lighting conditions when compared to the control group, implying that there was a form of metabolic inertia at the early laying phase. The absence of notable differences in feed intake across all treatments when compared to the control suggests that, at the early laying phase, hens are more interested in metabolic homeostasis than in external lighting signals, maintaining a reasonably stable appetite regardless of lighting colour and intensity. This is corroborated by previous studies (Blatchford *et al*., 2012), which reported minimal influence of lighting conditions on feed consumption at the early laying phase.

Egg mass across all treatments was not significantly affected ($p>0.05$) by the lighting conditions, when compared to the control (34.40). This suggests that egg mass is less responsive to environmental signals. Egg mass is largely determined by nutrient uptake, oviduct growth, and the production of yolk precursors, most notably vitellogenin, whose synthesis is triggered by oestrogen (Kang *et al*., 2023). Since reproductive hormones are regulated by light penetration through the pineal gland (Li *et al*., 2020), it is strange to see that egg mass did not differ significantly across treatments. Earlier research (Roberts, 2004) had supported this claim that egg mass (weight) is more heritable and less affected by immediate environmental signals.

The varying lighting conditions influenced the FCR across treatments (Table 1), particularly as the FCR of hens exposed to blue light at 9.0 lux (2.75) was lower than the control (3.82). This suggests that improved lighting conditions enhanced the hens' ability to utilise nutrients in feeds for egg production. Biochemically, the exposure of laying hens to blue light regulates the serotonergic system and enhances melatonin secretion (Zhao *et al*., 2021), which consequently stabilises metabolic rates and reduce oxidative stress. The observation from this study is supported by past research

(Pap *et al*., 2024), which asserted that blue light at optimum intensity improves FCR due to less physical exertion and improved thermal comfort.

The interaction of lighting colour and intensity significantly affected the HDEP (Table 1) of hens across treatments (78.2±9.4-Blue 9.0, 79.3±5.8-Green 9.0, 79.0±8.0-Red 9.0, 80.0±6.8-White 9.0), when compared to the control (61.4), suggesting that lighting conditions influence ovarian steroidogenesis and oestrogen production. For instance, blue and green light at high intensity increases aromatase enzyme activity, causing elevated oestrogen secretion (Zhao *et al*., 2021), and red light increases stress alleviation, thereby making room for perfect ovarian function (Yang *et al*., 2016). These findings are corroborated by the assertion from previous research (Svobodova *et al*., 2015) that found that hens raised under high-intensity light had significantly higher oestrogen levels, which accounted for increased egg production.

Table 1: Effect of Interaction of Lighting Colour and Intensity on Performance of Hens at the Early Laying Phase

Colour	Intensity	Feed Intake	Egg Mass	FCR	HDEP
Control	0	$118.7±1.9^{ab}$	34.4±3.1	$3.8±0.3^{a}$	$61.4±0.6^{b}$
Blue	9.0	$118.8±2.1^{ab}$	44.9±3.4	$2.8±0.1^{b}$	$78.2±9.4^{a}$
	13.5	$115.9±3.2^{ab}$	40.5±6.1	$3.0±0.4^{ab}$	$70.0±5.5^{ab}$
	18.0	$118.6±0.8^{ab}$	39.4±1.9	$3.2±0.2^{ab}$	$74.4±3.7^{ab}$
Green	9.0	$120.7±0.4^{a}$	44.3±6.5	$2.9±0.4^{ab}$	$79.3±5.8^{a}$
	13.5	$119.3±1.5^{ab}$	43.0±2.2	$3.0±0.2^{ab}$	$75.4±3.9^{ab}$
	18.0	$118.6±1.8^{ab}$	41.3±2.0	$3.0±0.1^{ab}$	$76.4±3.7^{ab}$
Red	9.0	$118.7±2.0^{ab}$	42.5±2.3	$2.9±0.2^{ab}$	$79.0±8.0^{a}$
	13.5	$114.5±4.0^{b}$	40.7±6.0	$3.0±0.4^{ab}$	$74.1±11.0^{ab}$
	18.0	$118.6±4.1^{ab}$	39.9±5.5	$3.2±0.5^{ab}$	$76.7±10.5^{ab}$
White	9.0	$117.0±0.9^{ab}$	38.5±5.4	$3.2±0.5^{ab}$	$80.0±6.8^{a}$
	13.5	$119.8±1.3^{ab}$	43.8±4.6	$3.0±0.5^{ab}$	$78.0±5.9^{a}$
	18.0	$117.7±2.8^{ab}$	38.5±7.0	$3.4±0.9^{ab}$	$69.7±8.6^{ab}$
	SEM	1.4	2.7	0.2	4.1

^{abc}Means of treatments along the same column with different superscripts are significantly different ($p<0.05$), FCR= Feed Conversion Ratio, HDEP= Hen-Day Egg production

The effect of interaction of lighting colour and intensity on performance at the mid-laying phase is presented in Table 2. There was no significant impact of the varying lighting conditions on the feed intake across all treatments, when compared to the control (121.3g/day), implying that the tested lighting conditions did not significantly alter the physiological pathways linked to appetite and satiety in laying chickens at the mid-laying phase. Feed intake in laying chickens is tightly regulated and involves a complex interaction between metabolic signals, hormones, and neural pathways in the hypothalamus (Shojael *et al*., 2020). These control mechanisms are mainly aimed at maintaining energy balance. Although lighting conditions influenced reproductive performance, they exerted insufficient impact on hypothalamic appetite regulation to cause significant feed intake variations. This observation is supported by previous studies (Wichman *et al*., 2021), which asserted that different lighting spectra does not affect feed intake in laying chickens.

There was no significant effect of either lighting colour or intensity on egg mass across all experimental groups compared to the control. This signifies that egg mass is principally regulated by genetic factors and the physiological age of the hen during the mid-laying phase. Egg mass is largely controlled by genetic programming, particularly genes involved in yolk formation, albumen synthesis, and shell deposition, all of which are hormonally controlled and closely linked to the hen's reproductive maturity (Roberts, 2004). While changes in lighting may affect the rate of egg production (i.e., how frequently hens lay eggs), they do not appear to affect the biological capacity to produce eggs of a certain size (Nega, 2024). These findings are consistent with prior research (Huber-Eicher *et al*., 2013), which demonstrated that lighting environments do not significantly alter the biochemical processes determining egg size in laying hens.

The tested lighting conditions did not significantly influence ($p>0.05$) the FCR across all treatments when compared to the control (3.46), suggesting an interdependence of parameters. FCR is a derived parameter that directly depends on feed intake (input) and egg mass (output). If the numerator (feed intake) and the components of the denominator (egg mass) are relatively stable across all treatments, the feed conversion ratio is unlikely to show any significant difference (McDonald et al., 2010). This observation is corroborated by findings from previous studies (Zhao et al., 2019), which asserted that photoperiods and lighting intensities did not affect the feed conversion efficiency in broiler chickens.

The tested lighting conditions significantly affected ($p<0.05$) the HDEP of hens across treatments, when compared to the control (63.00). This implies that lighting conditions have an impact on cellular energy metabolism and antioxidant status within the reproductive tissues. A major way by which lighting conditions affect HDEP is through their influence on cellular energy metabolism and antioxidant status within the reproductive tissues, most especially the ovary. Light exposure, for example, can affect the activity of ovarian cell ATP-generating enzyme systems (Xie *et al*., 2021). Specific light wavelengths might enhance mitochondrial function and oxidative phosphorylation in ovarian cells, leading to increased ATP production and supporting higher rates of egg laying. Conversely, suboptimal or absent light (as in the control group) could lead to less efficient energy metabolism within the ovary, limiting its capacity for sustained high levels of egg production (Li *et al*., 2020).

Table 2: Effect of Interaction of Lighting Colour and Intensity on Performance of Hens at the Mid-Laying Phase

Colour	Intensity	Feed Intake (g)	Egg Mass (g)	FCR	HDEP (%)
Control	0	121.3±1.5	35.4±3.8	3.5±0.4	63.0±0.0[a]
Blue	9.0	119.8±0.6	39.2±4.8	3.1±0.4	81.0±0.1[b]
	13.5	122.4±1.1	43.6±4.5	2.8±0.3	77.0±0.0[ab]
	18.0	120.4±2.2	39.3±7.3	3.2±0.7	71.0±0.1[ab]
Green	9.0	121.1±1.8	43.2±1.4	2.8±0.1	80.0±0.1[b]
	13.5	119.2±0.5	42.2±4.6	2.8±0.3	77.0±0.1[ab]
	18.0	122.8±1.0	44.0±2.3	2.8±0.2	85.0±0.1[b]
Red	9.0	122.8±0.2	43.3±7.0	2.9±0.4	77.0±0.1[ab]
	13.5	121.7±1.2	42.9±1.6	2.8±0.1	75.0±0.0[ab]
	18.0	121.1±1.4	41.7±1.3	2.9±0.1	77.0±0.0[ab]
White	9.0	122.3±1.2	43.3±4.8	2.9±0.4	75.0±0.1[ab]
	13.5	118.5±3.4	40.3±4.8	3.0±0.3	70.0±0.0[ab]
	18.0	120.2±0.8	39.3±1.9	3.1±0.3	74.0±0.0[ab]
	SEM	1.2	3.5	0.3	0.0

[abc]Means along the same column with different superscripts are significantly different ($p<0.05$), FCR= Feed Conversion Ratio, HDEP= Hem-Day Egg Production

Conclusion and Recommendations

It was concluded that appropriate regimens of lighting colour and intensity, particularly green lighting at 9.0 lux of intensity, were of profound usefulness to enhance the performance and productivity of laying hens.

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