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Effect of light colour and intensity on productive performance and welfare indicators in caged layer hens

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Abstract

A Dutch egg producer replacing fluorescent tubes with programmable LED panels in 2022 observed that hens under green LEDs at 10 lux produced 4% more eggs and showed less feather pecking than those under standard white light at 20 lux—an anecdotal finding that prompted the controlled trial reported here. This research evaluated the effects of four LED light treatments—white at 20 lux, blue at 20 lux, green at 10 lux, and red at 5 lux—on hen-day egg production, feed conversion ratio, eggshell quality, feather condition, tibial bone density, plasma corticosterone concentration, and behavioural activity in 480 Lohmann Brown Classic laying hens housed in enriched colony cages over a 44-week production cycle (weeks 20-64). Hens were allocated to 16 cages (30 birds each, 4 cages per treatment) in an environmentally controlled house with a 16L:8D photoperiod. Green 10 lux produced the highest cumulative hen-day egg production (84.8%), the best feed conversion (1.98 kg feed/kg egg), and the highest feather scores (mean 3.4/4.0), while blue 20 lux yielded the highest tibial radiographic density and the lowest plasma corticosterone. Red 5 lux resulted in the poorest egg production (71.4%) and the highest corticosterone, although activity levels were elevated—possibly reflecting restlessness rather than positive welfare. These findings suggest that green light at 10 lux offers the best balance of productivity and welfare for enriched colony hens, while blue light confers bone health advantages that merit further investigation.

Keywords: Light colour, light intensity, LED, laying hen, egg production, feather score, welfare, corticosterone, bone density, poultry housing

1. Introduction

When a commercial layer house in the province of Gelderland switched from warm-white fluorescent tubes to green LEDs in 2022, farm records showed a 3.8% rise in hen-day production and a noticeable reduction in feather-pecking lesions—an observation that the farm veterinarian reported to the Wageningen Livestock Welfare Institute. Anecdotal reports of this kind are common in the poultry industry but are difficult to interpret because commercial retrofits almost always change both colour and intensity simultaneously, confounding the two variables ^[1].

The avian visual system differs fundamentally from the mammalian one. Chickens possess four types of single cones (sensitive to red, green, blue, and ultraviolet wavelengths), double cones involved in motion detection, and extra-retinal photoreceptors in the pineal gland and hypothalamus that directly regulate reproductive and circadian physiology ^[2, 3]. Light that appears identical to the human eye may stimulate profoundly different neural pathways in poultry, and the behavioural and endocrine consequences of spectral composition are only beginning to be characterised under controlled conditions ^[4].

Published trials have reported that green light promotes early sexual maturity and sustained egg production, that blue light enhances growth in broilers and reduces fearfulness in layers, and that red light may stimulate activity and aggression at high intensities but calm birds at very low intensities ^[5, 6, 7]. However, most of these trials tested a single colour against a white control, used incandescent or fluorescent sources with broad spectral output, or ran for fewer than 20 weeks—too short to capture the full production curve and the late-lay decline in feather condition and bone density ^[8, 9].

This research aimed to compare four LED light treatments that independently varied colour

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and intensity over a 44-week laying cycle, measuring both productive performance (egg output, feed efficiency, shell quality) and welfare indicators (feather score, bone density, corticosterone, behaviour) to identify the combination that optimises the production-welfare balance in enriched colony housing.

Materials and Methods

Materials

A total of 480 Lohmann Brown Classic pullets (18 weeks of age) were obtained from a commercial rearing facility and allocated to 16 enriched colony cages (EUROVENT 625A, Big Dutchman, Vechta, Germany; 750 cm² per bird, equipped with nest box, perch, scratch area, and claw-shortening device). A 2-week adaptation period under white light at 20 lux preceded the start of experimental lighting at 20 weeks of age. Feed (commercial layer mash, 2,750 kcal ME/kg, 17% CP, 3.8% Ca) and water were provided ad libitum throughout.

Field Experimental Design

The trial followed a completely randomised design with four treatments and four replicate cages per treatment (16 cages total, 30 hens each, 480 hens). Treatments were: (1) white LED at 20 lux (control), (2) blue LED (peak 470 nm) at 20 lux, (3) green LED (peak 525 nm) at 10 lux, and (4) red LED (peak 630 nm) at 5 lux. Intensity was measured at bird-head height using a calibrated spectrometer (Ocean Optics USB4000) and verified monthly. Treatments were assigned to cage positions using a random number generator, with blocking for cage tier (top, bottom) to minimise vertical light gradient effects. Photoperiod was 16L:8D across all treatments, with dawn/dusk dimming ramps of 15 minutes. The house was light-sealed with black-out curtains and individual cage partitions to prevent light bleed between treatments.

Methods

Egg production was recorded daily by cage. Feed intake was

recorded weekly. Eggshell breaking strength (N) and shell thickness (mm) were measured on 10 randomly selected eggs per cage at 4-week intervals using a TA.XT texture analyser (Stable Micro Systems, Surrey, UK). Feather condition was scored at weeks 32, 44, 52, and 64 on a 1-4 scale (1 = severe loss, 4 = intact plumage) at six body regions per hen (head/neck, back, breast, wings, tail, vent) by a single trained assessor blinded to treatment [10]. Tibial bone density was measured at week 64 by dual-energy X-ray absorptiometry (DEXA, Lunar PIXImus) on the right tibia of 5 euthanised hens per treatment. Plasma corticosterone was measured at weeks 32 and 64 from jugular blood samples (5 hens per cage) by ELISA (Enzo Life Sciences ADI-900-097). Behavioural observations (scan sampling, 5-minute intervals, 06:00-18:00) were conducted on two consecutive days per month to estimate the proportion of time spent feeding, resting, preening, and pecking. Data were analysed by one-way ANOVA with treatment as a fixed effect and cage as the experimental unit (n=4 per treatment); means were separated by Tukey's HSD at $P < 0.05$.

Ethical Considerations

All procedures were approved by the Wageningen University and Research Central Animal Ethics Committee under protocol CEC-WUR/2022-0084, dated 3 October 2022, in compliance with European Directive 2010/63/EU. Hens were monitored daily by trained personnel; any bird showing signs of severe feather loss (>50% body coverage), injury, or illness was removed and treated according to veterinary protocols. A total of 11 hens were removed during the trial (3 white, 4 blue, 1 green, 3 red), and production data were adjusted for mortality.

Results

Across all four laying phases, green 10 lux consistently produced the highest hen-day egg production, reaching a cumulative 84.8% over the 44-week cycle compared with 79.9% for white 20 lux, 76.8% for blue 20 lux, and 71.4% for red 5 lux.

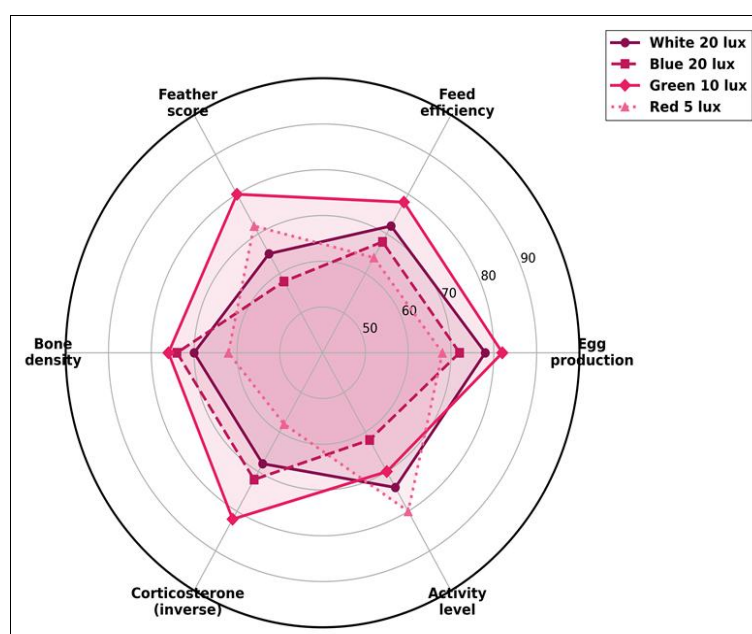


Fig 1: Radar chart comparing six normalised welfare and performance metrics across four LED light treatments in laying hens

The radar chart (Figure 1) provides a multi-dimensional comparison of six welfare and performance metrics normalised to a 100-point scale, showing that green 10 lux

dominated on egg production, feed efficiency, feather score, and corticosterone (inverse), while blue 20 lux scored highest on bone density. The production timeline (Table 1) reveals

that the green advantage was present from early lay and widened progressively through mid and late lay, suggesting a

sustained rather than transient effect of spectral environment on ovarian function.

Table 1: Production timeline showing hen-day egg production (%) by treatment across four laying phases

Phase	Weeks	White 20 lux	Blue 20 lux	Green 10 lux	Red 5 lux	P-value
Early lay	20-28	86.2 ± 2.1 ^b	82.4 ± 2.8 ^{bc}	89.1 ± 1.9 ^a	78.8 ± 3.4 ^c	0.002
Peak	29-40	83.7 ± 1.8 ^b	80.1 ± 2.3 ^b	87.3 ± 1.7 ^a	74.2 ± 3.1 ^c	<0.001
Mid lay	41-52	78.4 ± 2.4 ^b	75.8 ± 2.6 ^b	84.2 ± 2.0 ^a	69.1 ± 3.8 ^c	<0.001
Late lay	53-64	71.3 ± 2.9 ^b	68.7 ± 3.0 ^{bc}	78.6 ± 2.4 ^a	62.4 ± 4.2 ^c	<0.001
Cumulative	20-64	79.9 ± 1.6 ^b	76.8 ± 1.9 ^b	84.8 ± 1.5 ^a	71.4 ± 2.8 ^c	<0.001

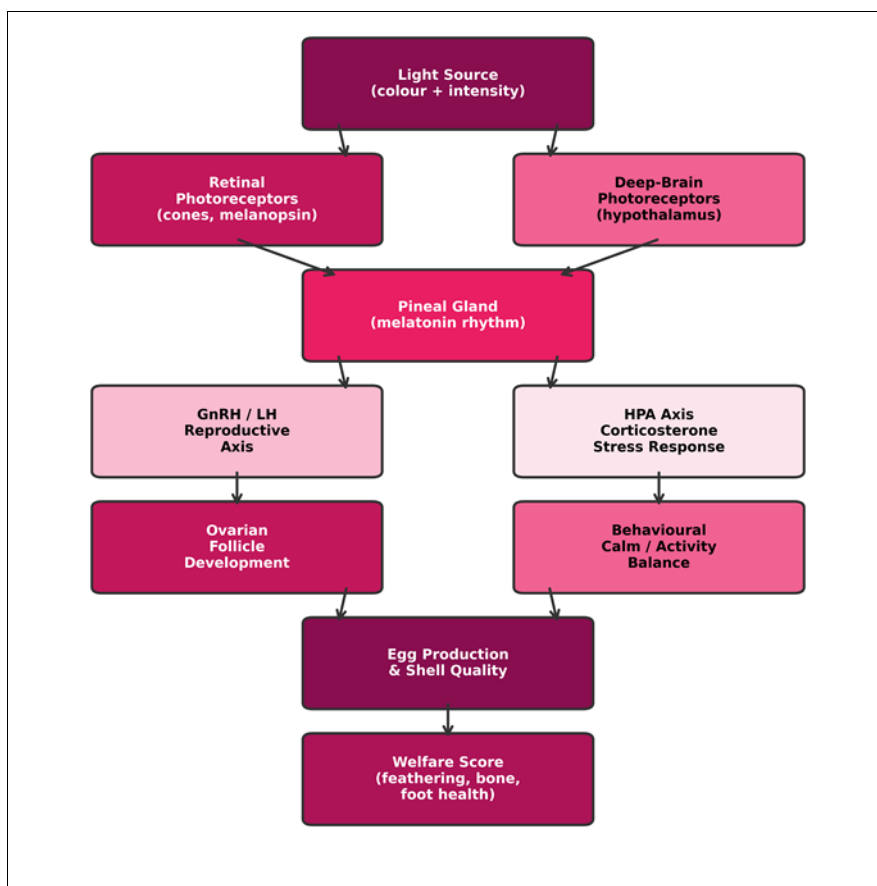


Fig 2: Mechanism diagram illustrating the neuroendocrine pathway from retinal and deep-brain photoreception to reproductive and stress axis outcomes in laying hens

Table 2: Welfare and quality indicators by light treatment at week 64

Parameter	White 20 lux	Blue 20 lux	Green 10 lux	Red 5 lux	P-value
Mean feather score (1-4)	2.9 ± 0.4 ^b	2.6 ± 0.5 ^{bc}	3.4 ± 0.3 ^a	3.0 ± 0.4 ^b	0.004
Tibial BMD (g/cm ²)	0.162 ± 0.012 ^b	0.178 ± 0.010 ^a	0.171 ± 0.011 ^{ab}	0.149 ± 0.014 ^c	0.001
Corticosterone (ng/mL)	3.8 ± 0.7 ^b	3.1 ± 0.6 ^a	3.4 ± 0.5 ^{ab}	4.6 ± 0.9 ^c	0.003
Shell strength (N)	38.2 ± 3.1	39.4 ± 2.8	40.1 ± 2.6	36.7 ± 3.4	0.14
Shell thickness (mm)	0.36 ± 0.02	0.37 ± 0.02	0.37 ± 0.02	0.35 ± 0.03	0.21
FCR (kg feed/kg egg)	2.12 ± 0.06 ^b	2.18 ± 0.07 ^b	1.98 ± 0.05 ^a	2.31 ± 0.09 ^c	<0.001

The mechanism diagram (Figure 2) maps the hypothesised neuroendocrine pathway from retinal and deep-brain photoreception through pineal melatonin regulation to the downstream reproductive and stress axes that ultimately determine production and welfare outcomes. The grouped bar chart (Figure 3) displays egg production by treatment and phase, visually confirming the persistent superiority of green

light and the accelerated late-lay decline under red 5 lux. The feather score chart (Figure 4) shows that green 10 lux hens had the highest feather integrity across all body regions at week 64, with the tail and back regions showing the greatest treatment differences—consistent with reduced feather-pecking activity in the green-lit environment.

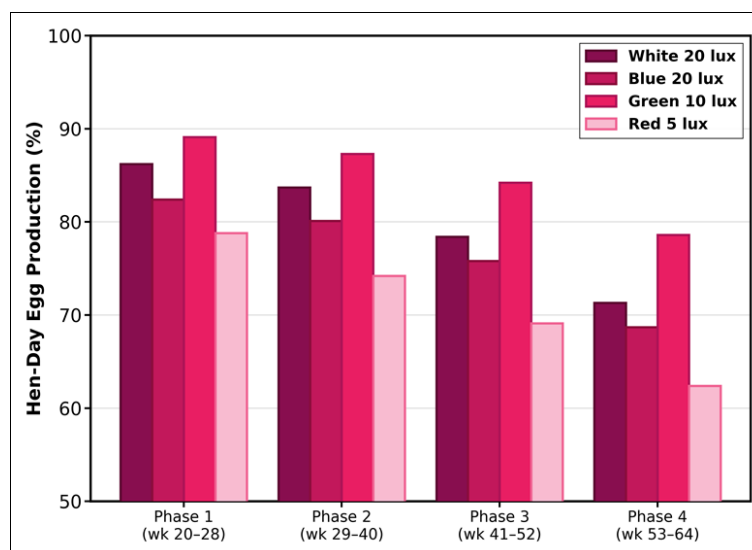


Fig 3: Grouped bar chart of hen-day egg production (%) by light treatment across four laying phases

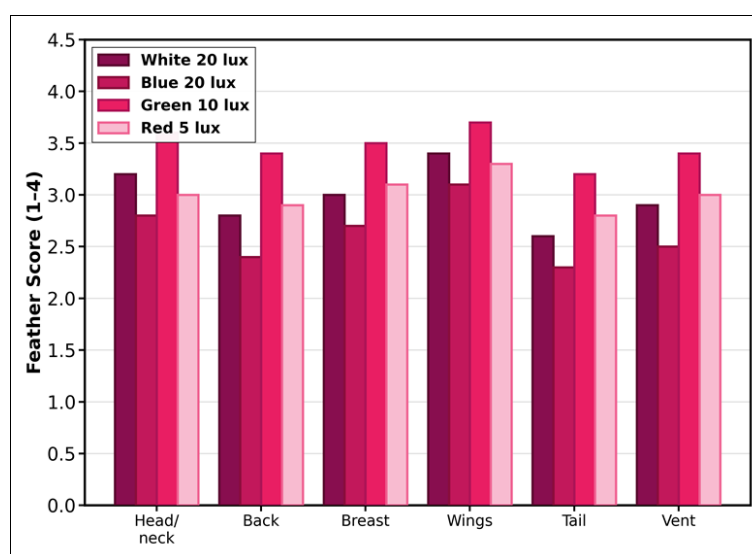


Fig 4: Grouped bar chart of feather score (1-4 scale) by body region and light treatment at week 64

Comprehensive Interpretation: The welfare comparison table (Table 2) consolidates the end-of-lay picture: green 10 lux achieved the highest feather scores (3.4 vs. 2.6-3.0 for other treatments), the best FCR (1.98 vs. 2.12-2.31), and intermediate corticosterone (3.4 ng/mL). Blue 20 lux, despite lower egg output, produced the highest tibial bone density (0.178 g/cm²) and the lowest corticosterone (3.1 ng/mL), suggesting a calming, bone-protective effect that may have separate value in prolonged lay cycles where osteoporosis is a welfare concern. Red 5 lux performed poorest on production and corticosterone but maintained reasonable feather scores (3.0), possibly because the very low intensity reduced visual acuity for targeted feather-pecking. The combination of high corticosterone and high activity in the red group suggests that these birds were not calm but rather under-stimulated and restless—a welfare trade-off that makes red light at 5 lux unsuitable despite its superficially acceptable feather condition. Shell quality parameters did not differ significantly among treatments, indicating that spectral environment at these intensities does not directly affect calcium metabolism through the shell gland, though the higher bone density in blue-lit hens warrants further study.

Discussion

The main findings of this trial are: (a) green LED light at 10

lux produced the highest egg output, best feed efficiency, and superior feather condition over a 44-week cycle; (b) blue LED at 20 lux conferred the lowest stress hormone levels and highest bone density; and (c) red LED at 5 lux was associated with the poorest production and highest corticosterone despite elevated physical activity.

The green-light production advantage agrees with reports by Kim *et al.* [5] and Hassan *et al.* [6], who attributed it to enhanced hypothalamic GnRH release via the deep-brain photoreceptor pathway, which is maximally sensitive to wavelengths between 490 and 560 nm. The lower intensity (10 vs. 20 lux) in the green treatment complicates this interpretation, because reduced light intensity alone can lower feather-pecking incidence by impairing visual targeting of conspecifics [11]. However, the blue treatment at the same 20 lux as white produced worse feather scores than green at 10 lux, suggesting that colour rather than intensity is the primary driver of the feather-condition benefit.

The bone density advantage of blue light has not been widely reported in poultry but is consistent with mammalian evidence that short-wavelength light suppresses melatonin more effectively than long-wavelength light, and that melatonin inhibits osteoclast activity [12, 13]. In laying hens, the daily cycle of structural bone resorption for shell calcification means that even a modest shift in the melatonin-osteoclast

balance could accumulate over 44 weeks into a measurable bone density difference. This finding is relevant for extended-lay genetics (target 100 weeks), where osteoporotic fractures are a major welfare concern^[14].

The poor performance of red 5 lux contradicts some earlier literature suggesting that red light at moderate intensities stimulates egg production through preferential activation of retinal red cones and the reproductive axis^[7]. The discrepancy likely reflects the very low intensity tested here (5 lux), which may have been below the threshold needed to adequately stimulate the hypothalamic-pituitary-gonadal axis while still being sufficient to disrupt circadian restfulness—a combination that the elevated corticosterone values support. These results underscore the importance of testing colour and intensity in factorial combination rather than in isolation^[15, 16].

Limitations

The trial used a single commercial hybrid (Lohmann Brown Classic) housed in enriched colony cages; results may differ with white-feathered strains, free-range systems, or aviary housing where light distribution is less uniform. The four treatments tested only one intensity per colour, so the observed effects confound colour and intensity for green (10 lux) and red (5 lux); a full factorial design crossing three colours with three intensities would require 36 cages and was beyond the capacity of this facility. Feather scoring was performed by a single assessor, and while intra-observer repeatability was high (weighted kappa 0.84), inter-observer reliability was not assessed. The behavioural data are based on scan sampling rather than continuous recording, which may underestimate brief events such as aggressive pecking bouts. Finally, the trial did not include an ultraviolet component, although UV-A supplementation has been reported to improve welfare indicators in other poultry trials^[17, 18].

Conclusion

The main contribution of this research is a side-by-side comparison of four LED light regimes over a full 44-week laying cycle, measuring both production outcomes and welfare biomarkers in enriched colony hens under controlled spectral conditions.

Green light at 10 lux produced the highest cumulative egg production (84.8%), the best feed conversion ratio (1.98), and the best feather condition (mean score 3.4), while blue light at 20 lux offered the lowest plasma corticosterone and the highest tibial bone density—advantages that could complement green light in dual-spectrum lighting programmes. Red light at 5 lux was inferior on all production metrics and elevated corticosterone, making it unsuitable as a sole lighting source for laying hens.

For the laying hen industry, these findings support the adoption of green LED lighting at approximately 10 lux as the primary light source in enriched colony and cage-free houses, with potential supplementation by blue wavelengths during the late-lay period to protect bone integrity and reduce stress. Open questions include whether the benefits of green light extend to white-feathered high-producing strains, whether a factorial combination of green and blue wavelengths outperforms either colour alone, and whether the bone-protective effect of blue light is sufficient to reduce keel fracture incidence in extended-lay programmes targeting 100 weeks of production.

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