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Effects of far infrared ray illumination on the performance, blood biochemistry, and faecal microflora of laying hens at different production stages

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Abstract

This study investigated the effect of far-infrared ray (FIR) illumination on performance, blood biochemistry, and faecal microflora of laying hens at different production stages. A total of 360 Hy-line brown laying hens were randomly allocated in a 2 × 2 factorial arrangement with six replicates. Hens were distributed in two production stages (30–39 and 45–54 weeks-old). Each group was exposed to two light types (light emitting diode; LED and LED+FIR) in separate rooms. The LED treatment illuminated a wavelength of 650 ± 10 nm (0.65 ± 0.01 µm), while LED+FIR treatment emitted 15 ± 10 µm with an LED wavelength. The results showed an interaction between egg production stages and light types on the serum triglyceride concentration. The hens exposed to the LED+FIR and LED treatments showed similar egg production, feed intake, egg weight, feed conversion ratio (FCR), as well as albumen height, haugh unit, and shell thickness of eggs. LED+FIR substantially decreased the concentration of serum cholesterol (CHOL), HDL cholesterol (HDLC), and triglyceride (TG) compared to LED lighting. LED+FIR substantially reduced the number of total microbes, *Escherichia coli,* and *Salmonella* in faeces compared to birds exposed to LED light. These findings suggest that LED+FIR lights may improve hen health and the hen house environment.

Keywords biochemical profile, far infrared ray, faecal microflora, laying hens, performance

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Introduction

The chicken photoreceptor consists of rods, double cones, and cones and can recognize a broader light wavelength than humans (Soliman & El-Sabrout, 2019). Chickens are influenced in growth, reproductive hormones, and immune responses due to their sensitive response to differences in the light spectrum (Hassan *et al.*, 2014). Therefore, researchers have exposed chickens to several different light sources to discover their physiological effects on poultry.

Light-emitting diodes (LEDs) have been widely employed in the livestock industry over the last three decades, as they provide an easy means of controlling light wavelength and intensity (Benson *et al.*, 2013; Hassan *et al.*, 2014). Diffuser plates are sometimes applied to provide LED lighting in the infrared, negative ion, ultraviolet, and other ranges (Cho, 2008; Baxter & Bedecarrats, 2019). For this reason, it is important to determine which lighting options bring about or optimize desired effects.

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Far-infrared rays (FIRs) with a wavelength of 5–20 µm are more frequently used in industry than near- and mid-IR light. Organic compounds exposed to FIR have been reported to radiate heat (Liu *et al.*, 2022). The possible beneficial effects of FIR have been observed in species as diverse as humans and crops. Some researchers conducting FIR therapy trials have demonstrated that symptoms have improved in diseases such as diabetes, cardiovascular disease, stress, and depression (Sharma *et al.*, 2019). Moreover, FIR enhances the diffusion systems, including blood circulation, cell proliferation, and pain reduction (Lee, 2009; Hadimeri *et al.*, 2017; Hong & Jeoung, 2020). They have also reported that crops reared under FIR show increased phenolic compounds, isoflavone, and antioxidants (Fujiwara *et al.*, 2012; Azad *et al.*, 2018). In addition, FIR is presently used to safely dry or store some crops (Lee *et al.*, 2019). Poultry differentiate wavelengths between 350 and 700 nm, i.e., they can't perceive light on the FIR (Hofmann *et al.*, 2020). However, Son (2015) indicated that LED+FIR reduced the amount of ammonia and hydrocarbon gas present in broiler houses, improving the rearing environment.

The number of studies examining the impact of FIR light in poultry remains insufficient. Furthermore, no experiments have analysed the possible effects of FIR on laying hens to our knowledge. Egg performance parameters of hens could be affected by the advancing age of the hens and housing conditions employed (Petek *et al.*, 2009; Rayan, 2015), and interactions have been found between light colour and the age of hens (Poudel, 2020). Therefore, FIR was evaluated as a lighting system at different production stages in hens in the current study. The evaluation included biochemical changes in egg production, egg quality, blood profiles, and faecal microflora of laying hens. Such investigations may provide evidence of whether FIR light in hen houses improves hen health and the house environment for future studies.

Material and Methods

The study was carried out at the Poultry Experimental Station of the Department of Animal Sciences at Jeonbuk National University in Korea. The protocol for this study was approved by the local ethic committee (JBNU 2021-0179).

We kept a total of 360 Hyline brown laying hens in 24 windowless floor houses (235 × 180 cm; 3.5 birds/m^2) for 10 weeks. A completely randomized experimental design in a 2 × 2 factorial arrangement (four treatments with six replicates of 15 birds) was used, in which two groups of hens distinguished by production stage (Group 1: 30–39 weeks old; Group 2: 45–54 weeks-old) were both exposed to two different lighting systems (LED and LED+FIR). The LED-exposed group received light at a wavelength of 650 ± 10 nm (0.65 ± 0.01 µm), while the LED+FIR-exposed group received FIR wavelength (15 ± 10 µm) in addition to LED wavelength light via diffuser plates installed in the bulb. House bulbs were located 150 cm above the floor and photoperiod (16 h), luminous intensity (100 ± 10 lux), luminous flux (600 ± 15 lm) and light colour (dayglow colour; 5,700 k) were held constant. The litter was set in the rooms at a height of 5–7 cm before the arrival of hens. Air temperature (consistently 21–24°C) and humidity (consistently 50–60%) were measured inside each pen to ensure that any preferences were due to lighting and not temperature or humidity. Diets were based on corn and soybean meal, formulated to meet the nutritional requirements of laying hens as recommended in Korean Feeding Standards for Poultry (2017).

Hen-day egg production and egg weight were measured daily throughout the trial. Feed intake was measured at the beginning and the end of the experimental period. The feed conversion ratio (FCR) was calculated as the amount of feed consumed per unit of egg weight, excluding broken eggs.

Twenty eggs from each group were collected at the end of the experiment, weighed individually, and stored overnight at room temperature for subsequent measurement. Albumen height was measured using the TSS Egg multi-tester (Technical Services and Supplies Ltd, York, England). Egg internal quality was evaluated in Haugh units, as described by 100 logs (Height - 1.7 $Weight^{0.37}$+7.57). Eggshell thickness without the shell membrane was tested using a micrometre (Digimatic micrometre, Series 293 330, Mitutoyo, Japan).

Blood samples were taken by puncturing the wing vein of six birds in each group at the end of the experiment. Samples were collected in sterile syringes, centrifuged, and subjected to biochemical

examination. The separated serum was stored at -20 °C. The serum concentrations of aspartate transaminase (AST), alanine transaminase (ALT), cholesterol (CHOL), HDL cholesterol (HDLC), and triglyceride (TG) were measured using the colorimetric method in a biochemical analyser (Automatic Biochemical Analyser, Thermo Scientific, Konelab 20, Finland).

One gram of five faecal samples from each group were exposed to each light source on the floor for 24 h at the end of the experiment. Then, the samples were diluted with 9 ml of sterilized, distilled water. In this manner, samples were serially diluted from 10^4 to 10^9. Finally, 100 µl of each sample was plated onto Plate Count Agar (Difco Laboratories, Detroit, MI, USA), MacConkey Agar (Oxoid, UK), and SS Agar (Difco Laboratories, Detroit, MI, USA). The target of this method was to isolate the total microbes, *E. coli*, and *Salmonella*, respectively. The Plate Count Agar and MacConkey Agar plates were incubated for 24 h at 37.5 °C. The SS Agar was incubated for 48 h at 37.5 °C. All colonies were counted immediately after removing the incubator, as Park *et al.* (2018) described. The colony-forming unit (CFU) was expressed as $\log_{10}$.

The effects of egg production stages (30–39 and 45–54 weeks) and two light systems (LED and LED+FIR) were statistically analysed as a 2 × 2 factorial design on the performance, blood composition, and faecal microflora of the hens. All data were analysed using the General Linear Models (GLM) procedure of SAS version 9.2 (SAS Inst. Inc., Cary, NC, USA). Results were considered significantly different at P <0.05.

Results and Discussion

Table 1 shows that performance and egg quality were not influenced by any interaction between egg production stage (30–39 and 45–54 weeks) and light source (LED and LED+FIR). The lights used in this experiment did not affect (P >0.05) laying hen performance and egg quality parameters (Table 1). Our results indicated higher feed intake and egg weight in the hen aged 45–54 weeks than those aged 39–39 weeks (P <0.05). Eggshell thickness was lower in the 45–54 week-old hens compared to the 30–39 week-old hens (P <0.05) (Table 1).

Our findings on productive performance partially support an earlier study by Son (2015), who reported no differences between LED+FIR- and LED-raised broilers in weight gain, feed intake, and FCR. It may be related to a study reporting that that the eggshell thickness is decreased because of increased egg weight from 52 weeks of age in commercial laying hens (Padhi *et al.*, 2013).

Table 1 Effect of far infrared illumination on the performance and egg quality of laying hens at different production stages

Main effect	Egg production (%)	Feed intake (g/d)	Egg weight (g)	Feed conversion ratio	Albumen height (mm)	Haugh unit	Eggshell thickness (mm)
Weeks of age							
30–39	89.3	118 [b]	60.3 [b]	2.20	6.21	76.9	0.370 [a]
45–54	88.4	122 [a]	62.1 [a]	2.23	6.27	77.9	0.356 [b]
Light system							
LED	89.2	120	61.2	2.21	6.13	77.2	0.363
LED+FIR	88.4	120	61.2	2.22	6.35	77.6	0.362
SEM	0.578	0.332	0.245	0.018	0.095	0.482	0.003
			Probability > F				
Source of variation							
Weeks of age	0.43	<0.01	<0.01	0.12	0.77	0.51	0.02
Light system	0.46	0.90	0.99	0.47	0.29	0.80	0.86
Age × Light	0.84	0.59	0.31	0.52	0.28	0.38	0.19

[a,b] Means within a column with unlike superscripts differ significantly (P <0.05)

The results suggested no interactions between egg production stage and light system for serum AST, ALT, and CHOL, though there was an effect on the concentration of serum triglyceride (P <0.05) (Table 2). Serum concentrations of AST, ALT, CHOL, and TG were higher in the 45–54 week-old hens than the 30–39 week-old hens (P <0.05) (Table 2). CHOL, HDLC, and TG concentrations in the blood were lower in in hens under the LED+FIR light than those under the LED light (P <0.05) (Table 2).

AST and ALT concentrations in the blood are used to detect cell damage in organs such as the liver or heart (Huang *et al.*, 2006). Indeed, additional AST and ALT are often released in the blood when problems occur in those parts (tissue, liver, heart) of the body (Huang *et al.*, 2006). It is well known that the aging phenomenon is generally followed by cell alteration (Ahmed *et al.*, 2017). Therefore, the augmentation of AST and ALT levels in the blood of older laying hens is probably due to their physiological stage. Animals also accumulate fat in their last stages of production (Hamed *et al.*, 2014). This tendency could explain the higher CHOL and TG concentration in the blood of older hens. The observed effects of FIR illumination on CHOL, HDLC, and TG concentrations in serum might be because of a warming effect of FIR that affects the reduction in CHOL and TG in tissues and organs (Song *et al.*, 2012; Didi & Yanmei, 2021). Additionally, decreased fat in FIR-exposed rats implies that the warming effect of FIR could induce vibration in tissues and organs, similar to exercise activity (Yamashita, 2012). Accordingly, these results could account for the reduction in serum concentrations of CHOL, HDLC, and TG in hen exposed to FIR, possibly related to the warming effect of FIR. Conversely, Beever (2009) noticed no reductions in body mass index, HDLC, and TG levels of subjects (humans) exposed to two weeks of FIR. The understanding of these opposite findings requires further exploration of the effect of FIR on CHOL and TG. In contrast to our study in which AST and ALT concentrations in blood were not influenced (P >0.05) by the LED+FIR light system, Son (2017) reported that broilers illuminated by FIR light decreased (P <0.05) these blood constituents (AST, ALT). The specific genetics or metabolism of chicken breeds (Ross ♂ ≠ Hyline ♀) added to the different light intensities (24 lux ≠ 100 lux) used in the two experiments could be the reasons for these conflicting results. Nevertheless, deeper investigations are warranted to clearly understand the influence of FIR light on blood metabolites such as ALT, AST, CHOL, and TG.

Table 2 Effect of far infrared illumination on the blood composition of laying hens at different production stages

Main effect	AST (IU/l)	ALT (IU/l)	CHOL (mg/dl)	HDLC (mg/dl)	TG (g/dl)
Weeks of age					
30–39	160 [b]	1.33 [b]	128 [b]	14.6	1,541 [b]
45–54	169 [a]	1.96 [a]	144 [a]	11.9	1,937 [a]
Light system					
LED	168	1.89	162 [a]	15.0 [a]	2,263 [a]
LED+FIR	160	1.41	111 [b]	11.5 [b]	1,215 [b]
SEM	4.21	0.580	8.44	3.19	65.34
			Probability > F		
Source of variation					
Weeks of age	0.03	0.04	0.05	0.11	0.01
Light system	0.06	0.11	<0.01	0.04	<0.01
Age × Light	0.44	0.30	0.06	0.76	0.04

[a,b] Means within a column with unlike superscripts differ significantly (P <0.05)

AST: aspartate aminotransferase, ALT: alanine aminotransferase, CHOL: cholesterol, HDLC: high density lipoprotein cholesterol, TG: triglyceride

The present results showed no interaction between production stage and light system on the faecal microflora on the floor of the hen house (Table 3). There was a reduction in the number of total

microbes, *E. coli,* and *Salmonella* microbes in the faeces of the hen house exposed to the LED+FIR light compared to the LED light (P <0.05) (Table 3).

In another study related with pathogenic microbes, Khan *et al.* (2020) observed that the frequent exposure of mice abdomens to FIR substantially decreased several pathogenic microbes (phyla Tenericutes and Deferribacteres). Yamashita (2012) reported that FIR energy radiation has an antibacterial effect on *Staphylococcus aureus* and *E. coli*. Huang (2004) explained these results by noting that organic matter is vibrated by FIR, which deactivates pathogenic microflora and causes the internal temperature to rise. The pathogenic microbes on the floor of the hen house have been shown to be important environmental factor affecting egg safety and hen health (Jones *et al.*, 2015). Our results suggest that LED+FIR light in hen houses reduces microflora on the floor that affect the environment and microbiology.

Table 3 Effect of far infrared illumination on the faecal microflora on the floor of the hen house

Main effect	Total microbes	*E. coli*	*Salmonella*
	---------- log_{10} CFU/g ----------		
Weeks of age			
30–39	10.1	5.57	5.39
45–54	10.1	5.57	5.37
Light system			
LED	10.5 [a]	5.70 [a]	5.56 [a]
LED+FIR	9.71 [b]	5.44 [b]	5.21 [b]
SEM	0.352	0.480	0.321
	Probability > F		
Source of variation			
Weeks of age	0.69	0.98	0.75
Light system	<0.01	<0.01	<0.01
Age × Light	0.95	0.74	0.95

[a,b] Means within a column with unlike superscripts differ significantly (P<0.05); CFU, colony forming units

Conclusions

FIR used in conjunction with LED is a valuable lighting system for laying hens. It decreased the serum concentrations of CHOL and TG in hens without negative effects on layer performance and egg quality. In addition, FIR light reduced the number of pathogenic bacteria (*E.coli* and *Salmonella*) on the floor of the hen house. Further research is necessary to elucidate the impacts of FIR on poultry.

Author' contributions

CI Lim collected literature and drafted the manuscript; HW Kim, AS You conducted the experiment and provided the technical help. KN Heo, HJ Choo reviewed the manuscript. All the authors read and approved the final manuscript.

Conflict of Interest Declaration

The author declares no conflict of interest.

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