

Red LED Lighting in Poultry Facilities improves Egg Production - a field study

I.J. Reddy, Ashish Mishra, S. Mondal, P. Arul Suresh, C.G. David,
R.K. Gorti and Vaibhav B. Awachat¹

Abstract

The objective of this study was to design a novel LED bulb and to establish the effects of different wavelengths of light on egg production in White Leghorn hens. From 28 to 72 weeks of age (woa), 20000 White Leghorn birds were divided into two groups consisting of 10,000 birds in each group (control=10000 and treated n=10000). The birds were housed in cages under a three-tier battery system with free access to ad libitum water. All White Leghorn birds were fed on the same layer ration as per the standard recommendations and were provided 16 h light and 8 h darkness. In the treated group the White Leghorn layers were exposed to red LED light (650nm) whereas in the control group, the birds were exposed to white incandescent light (450nm of wavelength). Daily egg production was recorded for both the groups at the same time for a period of 45 weeks. Feed intake in the treated group was low, but not significantly ($P>0.05$) affected by the treatment. The mean percentage of egg production was 88.20 in the treated group as against 85.82 in the control group. Egg production increased significantly ($P<0.05$) in White Leghorn hens exposed to red LED lights relative to the birds exposed to incandescent light. The red LED is highly cost effective. The cost economics were calculated based on an anticipated gain in egg production by 0.5% at 85% egg production over 10000 White Leghorn birds from 28 woa to 72woa. By utilizing red LED light and taking advantage of the unique spectral requirements of poultry, farmers can reduce stress and mortality, regulate circadian rhythm, and substantially increase the production of eggs with increased revenue while reducing energy use and other input costs.

Keywords: Poultry, Egg production, White leghorn.

Introduction

Domestic hens start reproductive development after sensing an increase in day length. This happens when more light is absorbed by a portion of the brain called

¹ ICAR-National Institute of Animal Nutrition and Physiology, Hosur Road, Adugodi, Bangalore. India

the hypothalamus, which secretes hormones and controls the part of the nervous system responsible for regulating reproductive performance in White Leghorn birds. Red LED spectrum of light is attributed to the deep-tissue penetration, extra retinal photoreceptor-mediated hypothalamic gonadotropin-releasing hormone (GnRH) mRNA expression and activation of the hypothalamo-pituitary-gonadal axis (HPG axis) and influence egg lay (Reddy *et al* 2012). The observation that red light with longer wavelengths of light (650 nm) is more gonado-stimulatory than shorter wavelengths (450nm of light. *i.e.* incandescent light) of light are not well established in poultry. However the precise mechanism is unknown. Further research has shown that the colour of light plays a key role in the behaviour, growth and reproduction in poultry (Prescoth and Wathes 2000; Reddy *et al* 2012). However, White Leghorn birds sense light through the retinal photoreceptors (Lewis and Morris 2000) and the extra retinal photosensitive cells in the brain (Nakane *et al.* 2010, Sharp 2005, Mobarkey *et al.* 2010) play a role and stimulate reproductive axis. It has been observed that shorter wavelengths of light (incandescent light) are involved in growth and behaviour through retinal photoreception (retina of the eye) and longer wavelengths of light (red light) stimulate the egg lay/gonadal axis through extra retinal photoreceptors at the hypothalamus by penetrating through the skull (Joseph *et al.* 2009; Reddy *et al* 2011; Shimizu and Bedecarrats 2006).

Research indicates that the photoreception by hypothalamic opsins deep in the brain act as photoreceptors to various wavelengths of light, such as vertebrate ancient opsin responds to 460–500 nm wavelengths (Halford *et al.* 2009). Light perceived by photoreceptors within the hypothalamus is transduced into nervous impulses that initiate the synthesis and release of GnRH (Chaiseha and El Halawani 2005; Shimizu and Bedecarrats 2006), thereby triggering the events of the HPG axis, resulting in the development of gonads (Sharp 2005). Nevertheless, as observed in mammals, the relative sensitivity of the avian pituitary to GnRH stimulation and the hypothalamic GnRH content is dependent on the physiological age, sex, and stage (Guemene and Williams 1999). This study also looks into the relationship between the red spectrum of light (longer wavelengths of light) on productive performance of hens which can lead to improved farm productivity and increased revenue, while lowering energy costs.

Material and Methods

This study was carried out on a commercial poultry farm near Mysore. Two poultry units (sheds) consisting of ten thousand White Leghorn birds each with

same age group were selected. White Leghorn birds in the treatment group were exposed to red spectrum of light from 28 weeks of age to 72 weeks of age. LED bulbs with red light with 20 lux were fixed in place of white incandescent lights in the commercial poultry farm so as to provide uniform intensity of light to all the White Leghorn birds within the group without any variation as for source of light with an intensity of 4 W/m² at bird-head level. Four Watts per square meter units were used because extra retinal photoreceptors located in the bird's head detect energy level penetrating through the skull. The control group was housed in the adjacent poultry shed provided with normal incandescent light bulbs and served as controls. Both the poultry sheds were open sided houses with natural lighting during the day time and the red light supplemented during the night to the treated group, with white light to the control group. The lighting schedule was 16h light and 8h darkness.

Daily egg production was recorded for each group at the same time for 45 weeks. Mean weekly egg production was recorded from both the groups. Clean water was made available round the clock throughout the experimental period. Feed intake in both the groups was recorded. Cost economics by utilizing red LED bulbs were calculated by taking into the account feed intake, egg production and electricity savings. Difference in egg production varies on so many unforeseen conditions such as disease outbreak, mortality and stress. Though there was 2.38% increase in egg production for a period of 45 weeks, the cost economics were calculated with an anticipated increase in egg lay by 0.5% as a standard to calculate the cost economics. Cost economics are presented in detail in the following Table.

Table 1. Cost economics of using red LED bulbs in poultry layer farm containing 10,000 white leghorn birds:

a. Egg Production:

Weeks		Days (Total number of days) (45x7)	Production	Total Eggs (Nos) (85%)	Anticipat- ed Increase (%) 50eggs/day	Egg Production Increase in egg produc- tion 50 eggs/day. Eggs for sale per day 40. Total eggs for 315 days 315x40 (12,000)		Rate of one egg (Rs.) (12000 x3.55)	Amount (in Rs.)
			Per day/ bird						
28 -72	4	315	1	8500	0.50	40	12,000	3.55	42600

Savings from 0.5% increase in egg production for 45 weeks or 315 days = Rs. 42,600

b. Electricity Saved:

No. of CFL	Watt	Hours On	Total (W/d) Kilowatt	No. of TL	Watt	Hours On	Total (W/d)	No. of Days	Rate p/unit	Amount (Rs)
80	13	5	5 (80 x 13x5 = 5200 watts or approximately 5 KW units	6	54 Or 40	6	2 6x54x6=1944 or approximately 2 units	315	4.50 7 (5+2) x315 day X Rs. 4.50 = 9922.5	9,920
80 Red LED	5	5	2 80x5x5= 2kilowatts	6	30	6	1 6x30x6=1080 Or 1 kilowatt	315	4.50 3(2=1) x 315 days x Rs 4.50 per unit = Rs. 4250	4,250
Savings										9920-4250 = 5,670

Savings from electricity

Cost Economics by using Red LED lights: (42,600+5,600) = Rs. 48270/-

Profits of using Red LED lights over 10,000 WLH hens per 10,000 flock: **Rs. 48,270/-.**

Application at village level: It would help poultry farmers in meticulous use of lighting for better egg production; a Red LED bulb with 4 watts capacity is sufficient to provide lighting in 200 sft room at village level. This technology represents the best option for being energy friendly and cost effective to farmers.

Statistical analysis

The data was analysed by taking weekly percentage of egg production between control and treated groups and analysed for test of significance by using statistical package of Graph Pad prism 5 software, San Diego, USA. A value of $P < 0.05$ was considered statistically significant.

Results

Egg production percentage was calculated between the weeks within the same group and between the two groups. At 28 woa, White Leghorn birds maintained under red light had a higher level of production than White Leghorn birds under normal spectrum of light ($p<0.05$). From 69 to 72 woa White Leghorn birds maintained under red light had a higher level of production non-significantly than White Leghorn birds under normal light ($p>0.01$). Similarly from 58-60 woa, White Leghorn birds maintained under red light had a higher level of production than those under normal light ($p>0.05$). The total percentage of egg production in treated white leghorn birds (red LED) was 88.20 per cent as against 85.82 per cent in the control for a period of 45 weeks (28-72 weeks or 315 days). Overall, there was a significant difference in egg production by 2.38 per cent (Fig.1) between the two light treatments. There was a significant ($P<0.05$) difference in production at other weeks of age (Table 2). Feed consumption was measured weekly to determine if there was a difference between light treatments. Overall there was no significant difference in feed consumption between light treatments ($p>0.05$). The difference in consumption of feed between control and treated groups were not included in cost benefits. Cost benefits were calculated on an anticipated increase in egg production at 0.5 per cent with an average of 85 per cent of egg lay throughout the laying period. Based on this, cost economics could be calculated for 2.38 per cent increase in egg production.

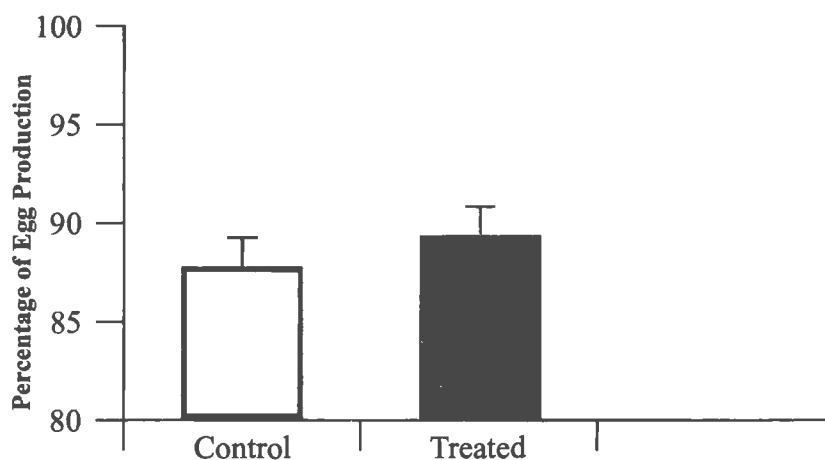


Fig. 1. Difference in percentage of egg production in birds exposed to normal spectrum of light (450 nm wavelength) and red spectrum of light (650 nm of wavelengths of light). Difference in egg production between Control and Treated birds was significant at $p<0.05$.

Table 2. Weekly percentage of egg production between the control White Leghorn birds exposed to normal light and treated White Leghorn birds exposed to red LED light

Weeks (Woa)	Percentage of egg production		Weeks	Percentage of egg production		Weeks	Percentage of egg production	
woa	Control (450nm)	Red (650nm)	woa	Control (450nm)	Red (650nm)	woa	Control (450nm)	Red (650nm)
28	89.90	90.94	43	85.98	87.59	58	86.05	86.45
29	91.01	98.99	44	85.06	89.18	59	86.52	87.88
30	89.95	92.35	45	84.26	84.28	60	84.08	85.13
31	88.80	91.56	46	83.45	86.19	61	82.52	85.94
32	89.51	91.79	47	83.82	85.95	62	85.01	85.99
33	89.18	93.94	48	88.77	89.40	63	84.95	86.35
34	89.36	90.95	49	89.53	90.37	64	83.80	85.56
35	88.93	91.39	50	88.19	91.05	65	79.51	81.79
36	87.31	88.29	51	87.43	91.22	66	83.18	83.94
37	85.18	91.71	52	85.98	87.59	67	82.36	85.95
38	82.17	85.26	53	85.06	89.18	68	83.21	85.89
39	86.44	87.51	54	84.26	84.28	69	86.05	86.45
40	84.59	86.26	55	83.45	86.19	70	86.52	87.88
41	87.86	90.59	56	83.82	85.95	71	84.08	85.13
42	87.43	91.22	57	83.21	85.89	72	85.39	86.99

The values with different superscripts in a row indicate significant difference between control and treated groups at $P < 0.05$.

Discussion

This paper describes the role of red LED lights on photosensitivity and egg lay in White Leghorn hens in commercial poultry facilities. These results demonstrated for the first time (at the field level) the effect of intensity and duration of light on the reproductive performance of laying hens during the active period of egg lay (28–72 weeks of age) in hens. This study shows that under tropical and subtropical conditions with a prevailing photoperiod of 12:12 L/D, additional lighting for 5 h to long wavelength red light (650 nm) significantly ($P < 0.05$) increased egg production compared to the usual incandescent lighting. This is attributed to the deep tissue penetration of red light activating the hypothalamic extra retinal photoreceptors, to stimulate the reproductive axis (Reddy *et al* 2011). Furthermore, light energy from red spectrum of light penetrates the feather, skin and skull to reach the receptor (Mobarkey, *et al* 2010).

The results suggest that adequate light intensity is required to stimulate receptors responsible for GnRH release in the hypothalamus because these receptors are suggested to be sensitive to the light directly passing through the skull instead of perception of light by eyes. Dim light (less than 5 lx) may not be able to penetrate the skull; thus, light at this intensity may be unable or less likely to excite receptors to release GnRH. Decreased testicular size in turkeys and follicle-stimulating hormone concentration in pullets under dim light (1 and 3 lx, respectively) also support this hypothesis. GnRH is responsible for secretion of sex steroids and gonadal development in both males and females. Sex steroids (androgens and estrogens) play an important role in folliculogenesis and egg formation in hen (Nakane *et al.* 2010, Sharp 2005, Mobarkey *et al.* 2010). They are also involved in expression of genes responsible for gonadotrophic and insulin-like growth factor-1 release. GnRH, gonadotrophic and gonadal hormones act simultaneously and enhance ovulation, egg formation and egg lay in hens. Overall, lower light levels can affect GnRH secretion, resulting in lower concentrations of steroid and gonadotrophic hormones and may ultimately cause low egg lay as observed in the control group exposed to incandescent light. The ability to penetrate to the extra retinal receptors is a function of the intensity and wavelength of the light source. Red spectrum of light fulfilled this and enhanced egg lay by 2.38 per cent in the treated group at the commercial poultry settings in hens (Shimizu and Bedecarrats, 2006, Lewis and Morris 2000, Reddy *et al.* 2012). Furthermore, different wavelengths of visible light spectrum influence the reproductive system of domestic avian species.

The observation in this study revealed that red LED (5 watts) light bulb within the red spectrum showed as the best option to promote optimum egg production without any significant impact on feed consumption, health and behaviour. A well designed, energy efficient lighting system led to higher lighting levels, better bird performance and lower energy costs. Red LEDs contributed directly to save 50% on light bill in this study. Results from this study will help determine the optimum lighting regimen to be used in an industry setting, and will help reduce the energy cost associated with incandescent lighting.

To conclude, in tropical conditions, the declining egg production in layer hens could be reversed by exposure to long wavelength red spectrum of light. Under tropical rearing conditions, artificial lighting with red light for 5 h over and above the 12-h natural photoperiod is sufficient for beneficial effects at farm level.

Furthermore, this approach and procedure could be extended to other species of economic importance such as ducks, geese and quails in tropics/subtropics in particular. This led to improved farm productivity in terms of increased egg production and increased revenue, while lowering energy and feed costs.

Acknowledgements

The authors are highly grateful to the Director, NIANP Bangalore for providing necessary facilities to carry out the work. The authors are also thankful to the Shri Krishna Poultry Farm, Mysore for accepting to conduct this trial.

References

- Guemene, D. and Williams, J.B., (1999). LH responses to chicken luteinizing hormone-releasing hormone I and II in laying, incubating, and out of lay turkey hens. *Domestic Animal Endocrinology*, 17, 1-15.
- Halford, Stephanie, Susana, S. Pires, Michael, Turton, Lei Zheng, Irene Gonzalez Menendez, Wayne, L. Davies, Stuart, N. Peirson, José M, García-Fernández, Mark W. Hankins, and Russell G. Foster. (2009). VA opsin-based photoreceptors in the hypothalamus of white leghorn birds. *Current Biology*. 19: 16, Page 1396-1402.
- Joseph, N.T., Morgan, K., Sellar, R., McBride, D., Millar, R.P and Dunn, I.C. (2009). The chicken type III GnRH receptor homologue is predominantly expressed in the pituitary, and exhibits similar ligand selectivity to the type I receptor. *J Endocrinology*, 202: 179–190
- Lewis, P.D. and Morris, T. R., (2000). Poultry and colored light. *World's Poultry Science Journal*, 56,189-207.
- Mobarkey, N, Avital, A, Heiblum, Rozenboim, I, (2010). The role of retinal and extraretinal photo stimulation in reproductive activity in broiler breeder hens. *General and Comparative Endocrinology*, 38:235-243.
- Nakane, Yusuke, Ikegami, Keisuke, Ono Hiroko, Yamamoto, Naoyuki, Shosei, Yoshida, Kanjun, Hirunagi, Shizufumi, Ebihara, Kubo, Presscott NB, and Wathes CM, (2000).Poultry and coloured light. *World poultry Science Journal*, 56,189-207
- Reddy I J, C.G.David, S. Selvaraju, G Ravi Kiran, and S Mondal (2012). Changes in GnRH and plasma LH concentration, steroid hormones, intersequence pause days and egg production in domestic hen exposed to different wavelengths of light during the later stages of production in domestic hen (*Gallous domesticus*)'. *Tropical Animal Health and Production* Volume. 44, Issue 6 Page 1311-1317.
- Reddy I. J, C.G. David, G. Ravi Kiran, and S. Mondal (2011).Pulsatile secretion of luteinizing hormone and GnRH and its relation to pause days and egg production in hens exposed to different wavelengths of light. *Indian Journal of Animal Sciences*. 81 (9): 919–923, September 2011.
- Shimizu, M and Bedecarrats, G.Y, (2006). Identification of a novel pituitary- specific chicken gonadotropin-releasing hormone receptor and its splice variants. *Biology of Reproduction*, 75: 800–808.
- Sharp, P.J., (2005). Photoperiodic regulation of seasonal breeding in white leghorn birds. *Annals of New York Academic of Sciences*, 1040, 189–99.