LIGHT EMITTING DIODE (LED): A NEW LIGHTING SOURCE IN POULTRY

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국문요약

점등은 가금 생산성에 직접적인 영향을 미치는 중요한 환경 요소이다. 조류의 망막은 척추동물 중 가장 정교한 원뿔세포 광수용체 시스템을 갖고 있어 감지된 빛에 대해 민감한 생리적 반응을 일으킨다. 따라서 빛의 요소 중 파장, 강도, 시간 등은 가금류의 골격, 근육 성장 및 성성숙과 같은 생산성과 행동학에 직접적인 영향을 미칠 수 있다. 그러한 이유로 가금류의 생산성 개선이나 복지 향상을 위한 많은 점등 연구 결과들이 보고되었다. 발광다이오드(LED)는 가금농가에서 쓰고 있는 기존 점등광원인 백열전구와 형광등에 비해 많은 장점들을 갖고 있어 최근 가금산업에 새로운 점등광원으로 소개되고 농가들의 LED 전구 사용은 점차 늘어가고 있다. LED 점등이 가금류에 미치는 영향을 평가하고자 닭, 오리에 대한 LED 점등시험을 수행하였으며 시험 결과 산란계에서는 적색 LED 점등시 산란 증가와 난각 개선, 육계에서는 황색 LED 점등시 체중 개선 효과를 보였다. 또한 육용오리 시험에서는 사육 초기에 황색 LED 점등시 체중 개선, 사육 후기에 녹색 LED 점등시 생산성 향상 효과를 나타내었다. 이와 같은 결과로 가금 종에 따른 LED 전구 파장의 선택적 사용은 에너지 효율 증가와 전기료 절감뿐 아니라 생산성 향상까지 기대할 수 있을 것이다.

Abstract

Lighting as a major environmental factor and exert direct impact on poultry production. The avian retina possesses one of the most sophisticated cone photoreceptor systems among vertebrates and thus responds differently on different wavelengths. There are wide varieties of lighting program especially wavelength, intensity and duration are considered during production phases which have direct physiological (i.e. skeleton, muscle growth and sexual maturity) and behavioral impact on poultry flock. Researches have conducted considering various lighting programs to find out proper lighting criteria for better bird's performance. Recently, Light emitting diode (LED), due to its various beneficial characteristics over traditional incandescent and fluorescent bulbs; emerging as a new lighting source in poultry, hitting the market at a rapid rate and becoming a selective choice of poultry farmers. Therefore, the experiments conducted using LED as a source of monochromatic light resulted that the laying hens and ducks reared under red light performed better in terms of increased egg production and egg shell thickness whereas broilers was heavier under yellow light. During starting phase the growth performance of duck is better in yellow light whereas in finisher phase ducks attained higher weight gain under green light. In this way, better production performance of different poultry species can be obtained by selectively using different light spectra by LED in a cost and energy efficient manner.

▶ **Keywords** : Poultry, LED, light, spectra, egg production, growth performance

I. Introduction

For sustainable poultry production updation and standardization of different research and managmental tools and application is essential to lower the cost and better flock health and production. The main environmental management factors which directly influence growth, FCR and egg production are mainly housing, light and temperature. Light; in the poultry house control the visual perception and behavioral process of the birds. Artificial light treatments, includes different light spectra, light duration, light quality and light intensity which is of foremost importance in the modern poultry management system (Andrews and Zimmerman, 1993; Rozenboim *etal.,*1999). A well designed lighting system with efficient lighting levels can improve bird performance with lower energy costs in the commercial poultry houses (Rozenboim *et al.,*1998). Proper lighting may also enhance the immune response of bird and play a vital role in alleviating the stress response in chickens (Xie *et al.,*2008) which in turn will improve production performance of the birds.

Several types of lighting systems, such as incandescent, fluorescent, compact fluorescent, fluorescent tube lighting and high intensity discharge lighting have been used on commercial poultry farms over the last few decades. Recently, a monochromatic light produced by LED lamps has been of growing interest in the poultry operations because of high energy efficiency, long operating life, availability in different peak wavelengths (Craford, 1985), low electricity consumption and low rearing cost (Rozenboim et al., 1998). The effect of monochromatic light on production performance and quality of the products of different poultry species has been investigated by many researchers. Bird performance is affected by light source, intensity, duration and color. There are conflicting reports on the impact of different light colors on bird’s performance. In a study with mature female Japanese quails, Woodard *etal.,* (1969) suggested that quails attain lower body weight when reared under green light and blue light than those reared under red light or white Light. Turkeys grew faster under blue light until 16 wks of age but by 24 wks those reared under red light and white light were heavier (Leighteon and Mason, 1976). Scott and Payne (1937) reported that red illumination produced more eggs compared to birds reared under green or blue light. Pyrzak *et* *al.* (1987) reported that total egg production was increased in the laying hen reared under red light, but it was decreased under blue light. The use of LED in current poultry industry in this way is of considerable importance as it has introduce new light on better production performance and minimize cost in broiler, turkey, layer and breeder production facilities with success. The present article is therefore prepared to highlight the significance and researches on LED in present poultry industry.

II. Importance of lighting in poultry

Lighting is an essential part of the physical environment and a powerful exogenous factor which control many physiological and behavioral processes. Light plays a vital role as it stimulates the secretory patterns of several hormones that control, in large part, growth, maturation, and reproduction. The action of light is physiological in that light enters into the bird's eye (retinal photoreceptors), is detected and nerve impulses are sent to the brain (extra-retinalphotoreceptors). The brain then coordinates the stimulus to stimulate the pituitary gland to secrete the necessary hormones for oculation (Banerjee, 1992; Lewis and Morris, 2000). These hormones carried via blood stream and reaches to target organs to exert their effect. It is integral to sight, including both visual acuity and color discrimination (Manser, 1996). Light allows the bird to establish rhythmicity and synchronize many essential functions, including body temperature and various metabolic steps that facilitate feeding and digestion.

Globally, poultry are reared in a variety of production systems. These include outdoor enclosures that basically utilize natural climatic conditions. Production houses of various sizes and their construction that have little to extensive control over light and other environmental factors. Very large homogeneous houses allow precise control of environmental factors, including temperature, humidity, air velocity, rate of air exchange, gases, light intensity, duration and color. Increased environmental complexity in poultry rearing facilities is recognized as a means to achieve productivity goals and to resolve welfare concerns (Newberry, 1995; Wemelsfelder and Birke, 1997; Mench, 1998).

Poultry behavior is strongly affected by light intensity and its manipulation is an important management tool affecting poultry production and well being. Light intensity could have played a part in these behavioral differences, and the birds may have preferred a brighter light for these particular behaviors as reported in Davis etal.(1999). Generally, brighter light will foster increased activity, while lower intensities are effective in controlling aggressive acts that can lead to cannibalism. Producers regularly use modern electronic systems to increase light intensity for short periods during grow-out to increase exercise and thereby reduce skeletal and metabolic disorders. Jurisdictions have established regulations in relationship to light intensity.

Lighting duration, i.e., photoperiod, is the second major aspect of light that could alter poultry performance. Most research involving light management has focused on this factor. Different photoperiodic regimes have been applied and tested over the years, while almost all of them have been shown to improve broiler welfare with conventional near-continuous lighting (Gordon, 1994). Lighting duration is largely dependent upon the age of chickens and housing type. Pattern of changing day length influences the layers and breeders performance. Increasing natural day light accelerate sexual maturity of growing pullets and stimulate egg production during laying period whereas decreasing day length retards sexual maturity of growing pullets and restrain egg production.

Color is the third major aspect of light. It is dictated by wavelength and it exerts variable effects on poultry performance. Daylight has a relatively even distribution of wavelengths between 400 and 700 nm. Light of different wavelengths has varying stimulatory effects on the retina and can result in behavioral changes that will affect growth and development (Lewis and Morris, 2000). The perception and response to different wavelengths of visible spectra is different by eye receptors which exerts variable effects on growth and production pattern of birds. Presently, researchers are conducting experiments on blue, green, red, white and yellow (in few reports) light wavelengths to find out the suitable lighting environment for better production performance of birds. Blue light has a calming effect on birds, while red will enhance feather pecking and cannibalism. Blue-green light stimulates growth in chickens, while orange-red stimulates reproduction (Rozenboim et al., 1999a,b; 2004). Some reports also show the influence of light color and intensity on immune response in broiler (Xie et al., 2008, Demas and Nelson, 1996; Nelson and Blom, 1994, Zulkifli et al., 1998).

In this way, it can be incurred that the role of light duration, intensity and color as a major environmental factor, has a direct impact on commercial poultry production and by adopting proper management ways and techniques the better results can be obtained.

III. lighting sources for poultry

Poultry farming is a very specific sector of agriculture; there are particular demands for lighting systems. Traditional lighting sources used in poultry industry were Incandescent and fluorescent bulbs. In commercial poultry farming there is relatively high light-level requirements in barns type production. Poultry producers require light sources with lights on for longer periods and with greater efficiency. The expense of lighting a poultry barn with 60-watt incandescent bulbs can be as much as 30-40 percent of the commercial operating cost. Therefore, lighting improvements should not only be beneficial for the birds but also energy efficient to minimize production cost.

The incandescent lamps are only about 5% efficient at converting energy to light and the rest is wasted as heat energy (Clarke and Ward., 2006). Incandescent lights also attract flies and other insects, and are quickly coated with dirt that further reduces the amount of available light. Incandescent lights also have a relatively short-rated life compared to other lighting types. For example, a 100 W, 1,000 hr (standard rated lamp) could be expected to last 63 days at 16 hr/day. Another lighting source that is used in poultry as a replacement of incandescent lighting is Compact Fluorescent Light (CFL). This source is more energy efficient, longer lasting light sources such as fluorescent which produce up to 4-5 times the number of lumens per Watt and have 10-15 times the life of incandescent lamps (Lewis and Morris, 1998). This source can save as much as 60 percent of lighting cost compared to incandescent bulb, industry wide, CFL bulbs poultry barn experience high failure rates due to the bulb sensitivity to power fluctuations (The Poultry Site Digital). In CFL the second common problem is dirt accumulation on spiral which reduces bulb lumen light output, plus the bulb naturally lose light output overtime (lamp lumen depreciation, LLD). Moreover, mercury in CFLs can create food safety concerns, which can substantially increase the mercury in waste.

Presently, it's a decision time for poultry farmers as they have to make a choice in between LED or other conventionally used light sources in farms. LED as of monochromatic (MC) lighting device has been introduced to poultry producers as an alternate lighting device. LED's are solid state device (P-N Junction semiconductor) that converts electrical energy directly into light trough a process called electroluminescence. The advantage of LEDs includes; it comes in various forms such as spot, linear or strip and monochromatic colors. LEDs are environmental friendly - energy efficient with 1/5th of the power consumption compared to incandescent lamps. LEDs contain no mercury, lowest total cost. LEDs lasts up to 100,000 hr compared to the typical incandescent bulbs at 1,000 hr or 20,000 hr fluorescent lamps (Mike Ostaffe, www.onceinnovation.com). LED is available in multi colours and gives immediate response and no preheat or starting time required for it. The energy efficiency of LED lamps can be very high (50 lumens/W) and life is much longer (up to 100,000 hr) than other light systems. If the technology can be adapted for poultry barn environments, it is expected that LED lighting systems will provide large on-farm energy savings in the future.

IV. Effect of different LED light color on production performance in poultry

Experimental trails were conducted to analyze the impact of different light colors from LED on growth and production performance of growing and laying chicken and ducks. The trials conducted are discussed here as under:

1) <u>LED red light improves laying performance in hens</u>

A study was conducted to find out the effect of monochromatic light on production performance, and egg quality of laying hens. A total of 144 fourteen-week-old Hy-Line Brown chickens were reared in cages and illuminated in 4 light treatment groups with 3 replicates (12 birds/ replication) for 14 to 60 wk. A 60 W incandescent light bulb (IL) used as a control, and white light (WL), blue light (BL), and red light (RL) produced using light emitting diode lamps were provided to form 4 light treatment groups.

The feed intake was significantly ($P<0.05$) increased when birds were reared under RL compared to WL and BL from 18-60 wk (Table 1). Egg production rate in various laying phase significantly ($P<0.05$) differed amongst the light treatments. Hens reared under RL produced significantly ($P<0.05$) higher number of eggs than those under IL and BL and hens reared under WL produced more eggs than those under BL from 18-60 wks. The egg weight was not affected during 18-60 wks of age due to any of the light regimen. Egg shell thickness improved in the RL group ($P<0.05$) which was statistically similar to WL group. It was concluded that monochromatic light has an influence on production performance and egg shell quality of laying hens. Birds reared under RL matured earlier, increased egg production and egg shell thickness.

Table 1. Production performance, egg weight and egg shell quality parameters of laying hens reared under different light spectra at 18-60 wk of age

*Treatments	Feed Intake (g/hen/d)	Egg production (%)	Egg weight (g/egg)	Egg shell strength (kg/cm^2)	Egg shell thickness (μm)
IL	117.31±9.66^{ab}	83.34±16.71^{bc}	59.51±6.26	3.91±0.52	0.38±0.02^{b}
WL	115.55±10.56^{b}	85.95±17.25^{ab}	59.27±4.37	4.04±0.77	0.39±0.01^{ab}
BL	115.52±13.28^{b}	80.92±21.62^{c}	58.28±11.16	4.19±0.72	0.38±0.02^{b}
RL	119.95±9.18^{a}	87.96±13.63^{a}	59.18±3.85	4.10±0.74	0.40±0.02^{a}

*IL, incandescent light (Control); WL, white light; BL, blue light; RL, red light
^{a,b,c} Means with different superscripts in the same column differ significantly ($P<0.05$).

Table 2. Body weight (g) in growing chicks from 1-5 wks of age at different monochromatic light sources

Wks/ *Treatments	Body weight (g)					
	WL	BL	RL	GL	YL	IL
1	204.17±3.00	212.10±2.77	200.83±5.83	207.03±8.52	196.67±4.64	196.23±9.51
2	516.50±13.81	541.77±5.79	523.43±13.94	508.07±10.41	545.63±13.09	519.37±9.11
3	1061.13±15.47	1066.23±10.63	1054.57±29.41	1016.77±15.80	1057.90±34.20	1015.20±25.41
4	1796.47±25.08	1781.57±13.09	1771.80±55.10	1763.23±42.81	1767.07±36.75	1720.47±30.87
5	2558.50±74.64	2550.90±47.43	2514.57±72.69	2548.50±110.53	2598.03±55.54	2525.50±46.55

*WL, white light;BL, blue light;RL, red light;GL, green light;IL, incandescent light (Control)

2) LED yellow light improves growth performance in broilers

In another experiment the effect of different light colors on growth performance of growing chicks was observed. Three hundred and sixty (n=360) day old chicks were randomly divided in to six groups of light treatment viz. white LED (WL), blue LED (BL), red LED (RL), green LED (GL), yellow LED (YL) and an Incandescent lamp (IL) as control. There were 60 birds in each group and each group was divided in to 3 replicates with 20 birds/replicate. The study was conducted from 1-5 wks of age to study the growing performance.

Body weight did not differ due to any of the LED treatments at any growth period (Table 2), however on critical analysis of data numerically higher value for body weight was found at YL treatment at 5th week of age. Birds were heavier ($P<0.05$) reared under YL, however the values were statistically similar GL treatment during 5thwk of age (Table3). The RL did not exert any influence on body weight gain and the birds obtained from this treatment were lighter compared to other treatments. In this study it was evident that birds perform better under yellow light than green, blue and red light and was concluded that yellow light (YL) could improve the growth performance in growing chick uptill 5 weeks of age.

Table 3. Body weight gain in growing chicks from 1-5 wks of age at different monochromatic light sources

Wks/ *Treat-ment	Body weight gain(g/n)					
	WL	BL	RL	GL	YL	IL
1	162.27±3.00	170.20±2.77	158.93±5.83	165.13±8.52	154.77±4.64	154.33±9.51
2	312.33±12.48^{b}	329.63±3.75^{ab}	322.60±8.72^{ab}	301.00±8.70^{b}	348.97±8.59^{a}	323.13±11.58^{ab}
3	544.63±15.40	524.43±7.71	531.13±17.35	508.73±7.52	512.27±25.52	495.87±16.42
4	735.33±28.67	715.33±10.77	717.23±26.54	746.47±28.28	709.17±44.98	705.23±32.35
5	763.47±53.31^{b}	769.40±46.67^{b}	742.77±18.35^{b}	785.27±67.88^{ab}	831.80±18.46^{a}	805.03±17.53^{ab}

*WL, white light;BL, blue light;RL, red light;GL, green light;IL, incandescent light (Control)
[a,b] Means with different superscripts in the same column differ significantly ($P<0.05$).

Table 4. Impact of LED light wavelength on laying rate (%) of laying ducks

Wks/ *Treatments	Laying rate (%)			
	IL	WL	BL	RL
21-30	56.40±2.92	52.59±2.74	52.53±2.71	59.74±2.92
31-40	68.02±0.82^{b}	67.44±0.64^{b}	57.60±1.00^{c}	71.63±0.81^{a}
41-50	65.81±0.71^{a}	65.85±0.98^{a}	50.57±1.22^{b}	67.96±0.59^{a}
51-60	61.28±0.98^{b}	64.23±1.06^{a}	56.66±1.17^{c}	64.32±0.79^{a}
61-70	46.62±2.37^{c}	51.40±1.49^{b}	50.50±1.12^{bc}	56.12±1.06^{a}

*IL, incandescent light (Control); WL, white light; BL, blue light; RL, red light
[a,b,c] Means with different superscripts in the same column differ significantly ($P<0.05$).

Table 5. Impact of LED light wavelength on egg weight of laying ducks

Wks/ *Treatments	Egg weight (g)			
	IL	WL	BL	RL
21-30	84.83±0.62	84.25±0.53	84.44±0.63	84.11±0.70
31-40	90.81±0.58^{ab}	86.01±3.21^{b}	88.94±0.69^{ab}	91.93±1.14^{a}
41-50	90.94±0.60^{bc}	91.64±0.46^{b}	90.03±0.65^{c}	93.18±0.37^{a}
51-60	86±41±0.54^{ab}	90.03±2.88^{a}	84.41±0.91^{b}	87.79±0.64^{ab}
61-70	87.00±0.49^{ab}	88.32±2.03^{a}	84.73±0.62^{b}	87.22±0.49^{ab}

[*] IL, incandescent light (Control); WL, white light; BL, blue light; RL, red light
[a,b,c] Means with different superscripts in the same column differ significantly (*P*<0.05).

3) LED red light improves laying performance in ducks

The report on the influence of LED lighting on egg production in laying duck has not been studied so far. The impact of different light colors by LED was also observed in an experiment on laying ducks. A total of 288 laying ducks were divided in to 4 lighting groups *viz* Incandescent light (IL, control), white light (WL), blue light (BL) and red light (RL). Each group had 3 replicates with 24 birds in each. All the birds were fed standard layer diet with proper feeding and watering facility. The whole experiment was conducted from 20th to 70th wks of age to study the impact of different light colors of LED on laying rate percent and egg weight. Laying rate (%) differed significantly ($P<0.05$) due to different light from 31-40, 41-50, 51-60 and 60-70 wks of age, however, during initial laying period (21-30 wks) it was remained unaffected (Table4). Laying rate was higher at RL group where as it was decreased in BL. Among all treatments lowest laying rate (46.62 %) was in IL but was greatest (56.12 %) in RL group during 61-70 wks of age. Egg weight was higher at RL group during 31-40 and 41-50 wks of age (Table 5), where as during 51-60 and 61-70 wks of age the values for egg weight was higher at WL group which was statistically similar to RL group. It was incurred from this experiment that laying ducks reared under RL can perform better in terms of laying rate (%). During initial laying period higher egg weight can be obtained from RL whereas egg weight on later stages improves in WL.

4) LED yellow and blue light improves growth performance in growing ducks

To study the impact of different light colors on growth performance in growing ducks, a total of 360 growing ducks were divided into 6 groups. Six experimental treatment with Incandescent light (IL, control), white light (WL), blue light (BL), red light (RL), green light (GL) and yellow light (YL) were prepared. Each treatment had 3 replicated with 20 birds. All the ducks were provided a standard grower diets. Body weight differed significantly during overall study period (1-6 wks of age, Table 6). Ducks reared in YL attain higher weight ($P<0.05$) during 1st, 4th and 5th wks

Table 6. Impact of LED light wavelength on body weight of growing ducks

Wks/ *Treat-ment	Body weight (g)					
	WL	BL	RL	GL	YL	IL
1	244.17±0.83^{b}	255.83±0.42^{ab}	260.83±3.41^{ab}	259.93±11.36^{ab}	272.23±7.48^{a}	246.63±1.10^{b}
2	674.17±1.50^{a}	658.33±3.56a^{bc}	655.00±8.20^{abc}	639.57±4.75^{c}	664.27±8.60^{ab}	649.53±8.93^{bc}
3	1329.10±6.68^{a}	1306.83±9.79^{ab}	1276.70±16.92^{bc}	1286.37±4.18^{b}	1286.53±12.61^{b}	1249.70±13.16^{c}
4	2055.53±5.62^{b}	2064.17±10.65^{b}	2064.13±18.76^{b}	2051.10±5.87^{b}	2109.37±4.02^{a}	2026.73±20.98^{b}
5	2769.57±18.30^{bc}	2730.23±11.51^{c}	2728.73±30.02^{c}	2784.80±4.61^{b}	2836.53±13.08^{a}	2744.17±17.03^{bc}
6	3487.17±14.57^{b}	3430.07±35.11^{b}	3478.67±8.67^{b}	3594.93±17.10^{a}	3559.50±20.85^{a}	3334.17±10.32^{c}

*WL, white light; BL, blue light; RL, red light; GL, green light; YL, Yellow light; IL, incandescent light (Control)
[a,b,c] Means with different superscripts in the same column differ significantly (P<0.05).

of age, whereas at 6th wk the body weight of ducks was higher reared under GL. It was concluded that for in itial body weight yellow light can be useful however for finisher phase duck can attain heavy body weight in green light.

V. Conclusion

Light emitting diode, a source of monochromatic light, has becoming farmer's choice due to its longer life, energy efficiency and better results of production performance in chickens and ducks. It can be summarize from the research trials discussed in this article that laying hens and ducks egg production performance better under Red Light. Yellow light improves the growth performance in growing chicks. During starting growth phase ducks performed better under Yellow light whereas Green light is beneficial for finisher phase of ducks. There is lack of literatures to justify the present results and our understanding of poultry responses to different light environment. Therefore more researches needs to be conducted in this aspect to standardize the light intensity, duration and the color wavelength for cost effective poultry production. LED in this way can act as a bridge and could help to explore the better bird's response in different light wavelengths for sustainable poultry production.

VI. References

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