THE EFFECTS OF LIGHT-EMITTING DIODE (LED) LIGHT WITH DEFFERENT COLOR ON THE GROWTH PERFORMANCE OF BROILER CHICKEN

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CERTIFICATE

This is to certify that the thesis entitled "THE EFFECTS OF LIGHT-EMITTING DIODE (LED) LIGHT WITH DIFFERENT COLOR ON THE GROWTH PERFORMANCE OF BROILER CHICKEN" submitted to the Faculty of Animal Science & Veterinary Medicine, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of Master of Science in Department of Animal Nutrition, Genetics & Breeding, embodies the result of a piece of bona fide research work carried out by Trina Biswas, Registration No. 17-08230 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

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DEDICATED TO

MY

BELOVED PARENTS

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The Author

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LIST OF ABBREVIATIONS

ABBREVIATION	FULL WORD
BW	Body weight
Ca	Calcium
CF	Crude fiber
CP	Crude protein
CFL	Compact fluorescent lamp
CORT	Corticosterone
CRI	Color rendering index
CSA	Canadian standards association
DM	Dry matter
DOC	Day old chicks
et al.	And others
FCR	Feed conversion ratio
g	Gram
H/L	Heterophil/lymphocyte ratio
HPS	High-pressure sodium
IBD	Infectious bursal disease
K	kelvin
Kg	kilogram
l	Liter
LED	Light-emitting diode
lm	Lumens
LYS	Lysine
Max	Maximum
ME	Metabolic energy
Meth	Methionie
Min	Minimum
ml	Milliliter
ND	Newcastle disease
nm	Nan meter
NS	Not significant

LIST OF ABBREVIATIONS(CON'D)

ABBREVIATION	FULL WORD
P	phosphorus
SD	Standard daviation
SEM	Standard error mean
TH4+	Thyroxine hormone
TI	Tonic immobility
Tryp	trypsin
UL	Underwriters laboratories inc.
UV	Ultraviolet
w	watt

LIST OF SYMBOLS

SYMBOL	FULL MEANING
@	At the rate of
+	Plus
<	Less than
>	Greater than
°C	Degree celcius
°F	Degree fahrenheit
%	Percentage
&	And
*	5% level of significance
**	1% level of significance
/	Per
β	Beta
λ	Lambda
:	Ratio

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ABSTRACT

Artificial lighting is one of the most powerful management tools available to commercial broiler producers. The study was carried out by a total of 150 day-old Cobb 500 broiler chicks were reared in Sher-e-Bangla Agricultural University Poultry Farm, Dhaka. This study aimed at comparing the performance of commercial broiler submitted to lighting using different LED colors or conventional incandescent lamps. This study maintain standard lighting program and were fed balance diet. The overall growth performance of broiler in red LED, green LED and 40W incandescent light were almost same. Body weight was comparatively better ($P<0.01$) among studies green light sources. Feed conversion ratio (FCR) and feed consumption was almost similar in red LED, green LED and 40W incandescent light. Uniformity (%) was significantly different ($P<0.01$) among studies, with the best results obtained with red LED light sources. It was concluded that the replacement of incandescent light bulbs by red and green LEDs does not cause any negative effect on the growth performance of commercial broiler. Therefore, switching to red and green LEDs may be can result in overall increased revenue for farmer because of the lower energy costs.

CHAPTER 1

INTRODUCTION

1.1 Background

The demand for food worldwide is expected to double by 2030. To meet that demand, producers are adopting new technologies that will enable them to increase production at a reduced cost with less stress on the environment. Most of these production technologies focus on enhancing traditional inputs such as water, air, nutrients, and housing. One largely unexplored production input is light. The poultry farming contributes positively to the Bangladeshi agribusiness economy. In Bangladesh, more than half of the people is depends on agriculture and livestock farming. The poultry sector is an integral part of farming systems and has created both direct and indirect employment opportunity, improve food security and enhanced supply of quality protein to people’s meals, contributing country’s economic growth and reducing poverty level in rural and urban areas of Bangladesh. Artificial lighting, characterized by the type of light source, wavelength and intensity, spatial distribution of illuminance and duration of photoperiod (mendes *et al*., 2010), acting directly on the behavior, physiology, visual comfort and welfare of the broilers.

The development and refinement of LED technology to meet the lighting needs of the poultry industry over the past 5 years has been a remarkable feat. As a general rule, the poultry industry is pretty conservative, and it has taken a while for the industry to become comfortable with LED technology. However, there is enough data available now that the industry is embracing LED technology and the energy savings it offers poultry producers. A good LED bulb is 80–85 per cent more efficient than an incandescent bulb. However, not all LED bulbs are the same, and poultry producers should invest time and do research before purchasing LED. Energy saving that can be expected from LED technology.

There are many benefits of choosing LED lighting for the farm. It has longest comparable lifespan. When compared to other lighting options, LEDs generally come out on top in their average rated life, luminous efficacy rating and overall energy savings. The average rated life of LEDs will vary from 15,000-100,000 hr, depending on the use and type of bulb. Most commercially available bulbs will list a rated life of 25,000-50,000 hr. There have been some failures of LED lighting equipment in barns because of overheating due to dust accumulation, water getting inside the bulbs during pressure washing of the barn etc. When purchasing LED bulbs for use inside a barn, select bulbs rated for wet, dirty environments that come with a warranty. LEDs tend to have a very high luminous efficacy rating when compared to other lighting types. LED bulbs have an average efficacy of 85 lm/W, compared to 70 lm/W for CFL and 15 lm/W for an incandescent bulb. T8 and T5 fluorescent tubes have high efficacy ratings operating in the 80-105 lm/W range. While LED tube lamps (TLED) that are used to replace T8/T5 fluorescent tubes have a rating of 100-130 lm/W, there are currently prototype LED tube lights that produce 170 lm/W, and research is looking at improving this value even further to above 200 lm/W in the future. High CRI LEDs generally have a CRI rating of 70-90. For good color perception, choose LED lights that have a CRI rating great than 85. Overall energy savings LEDs tend to require the least amount of energy to produce the required amount of lumens due to their high efficacy. As a result, a 60W incandescent bulb can be replaced with a 10W LED. This energy saving in combination with the long life of LEDs will save money on both energy usage costs and bulb (lamp) replacement costs.

1.2 State of the problems

The use of light-emitting diode (LED) lighting in agricultural applications is relatively new and has shown a lot of promise to date. This factsheet provides information on LED lighting, how to choose LEDs and what to look for when purchasing them for the farm. A cost comparison example of various lighting systems installed in the same barn is also provided. Lighting is an important component in most poultry facilities as it represents a large part of the monthly energy consumption. Traditionally, incandescent or fluorescent bulbs were used to provide the required level of light in barns. To reduce monthly lighting costs, farmers are looking for more energy-efficient lighting technology such as light-emitting diodes (LEDs). Embracing LED technology that reduces energy consumption and improves the overall business is good for both the farmer and society. There may also be production advantages to using specific spectrum lighting as a means to improve bird performance while decreasing light energy usage. Switching to LEDs can result in an overall increase in revenue because of the lower energy costs.

Many livestock farmers still utilize general-purpose residential and commercial 60W, 80W, and 100W incandescent lamps in their barns. These lamps are well suited to human environments, but incandescent light is not the same as sunlight, and the best light for humans is not necessarily the best light for animals. Animals have evolved living under the sunlight, whose spectrum differs substantially from that of incandescent light. Sunlight is a combination of all colors. Modern barn lighting systems attempt to mimic the sun's spectrum, which provides a continuous spectrum containing all colors with no gaps in between. Incandescent light effectively simulates sunlight at sunset, producing a continuous spectrum rich in reds with diminished greens and very little blue. However, this spectrum does not simulate midday sunlight, which is rich in blues and greens with diminished red. Some manufacturers try to put coatings on the bulbs to alter the spectrum, but this approach does not produce a continuous spectrum. Incandescent bulbs are also highly inefficient (producing more heat than light), burn out often, and require a fixture that is wet-location rated. All that will soon be moot, of course, as new production of incandescent lights is banned.

Compact fluorescent lamps (CFLs) have good efficiency and produce white light, but again, CFL light output is tailored to human vision. The white light is achieved by producing and combining narrow bands of red, green, and blue. As a result, there are large gaps in the spectrum between the red, blue, and green spikes, and many of the red, blue, and green wavelengths present in sunlight are lost. Blue light is exceptionally weak, and most of the deeper reds are lost. Overall, CFLs do a terrible job of mimicking natural sunlight. They are also hard to clean (because of their curly shape), contain small amounts of toxic mercury, require an enclosure to be wet rated, and do not dim well — plus their lifetime is shortened significantly when dimmed.

High-pressure sodium (HPS) bulbs offer excellent efficiency and high light output, with a color spectrum that is strongest in the reds and yellows, thus giving the bulbs their distinctive orange-yellow or amber hue. However, with CFLs much of the color spectrum is missing, especially the greens and blues. HPS lamps are also very difficult to dim are slow to warm up, require ballast for operation, have high upfront costs, and may contain sodium and/or mercury. LEDs are the most efficient and environmentally friendly of the agricultural lighting options, producing white light by combining a blue LED with red and green phosphors. The spectrum is near continuous with especially strong blues, but also ample green and red. While not exactly daylight, the LED spectrum provides a close approximation of daylight from a human's point of view, without the spectral gaps of other technologies. They also have the longest lifetime (up to 10 years with 24/7 operation), are highly rugged, are not susceptible to shock or vibration, and allow for color shifting and color control. LEDs have high upfront costs, but these costs are quickly recouped through energy savings, resulting in the lowest total cost of ownership for agricultural lighting options

1.3 Justification of the study

Energy savings associated with LED bulbs are as much as 80–85 percent compared to incandescent bulbs. This fact has been proven numerous times in field trials. If light levels are adequate during brood and grow periods, if the light dimmer does its job correctly, and if the birds are cared for properly. Birds perform just as well under LEDs as under other typical light sources found in chicken houses. While most LED work has been with broilers, recent work has been ongoing in both pullets and broiler breeders. Early results appear just as promising in pullets and breeders as in broilers. LEDs are a type of solid-state lighting as they emit their light from a solid semi-conductor chip or diode (usually made from silicone). This allows LEDs to have some very specific qualities that make them different from other lighting technologies, since they are not producing light from a filament (as incandescent light) or an excited gas in a vacuum tube (a compact fluorescent light (CFL)).

LEDs can withstand a rougher handling as compared to other lighting. Due to the lack of a filament, LEDs are able to withstand rougher handling and vibration, but dropping them is still quite hazardous to the bulb's life. LEDs are instant on/off lighting. LED lighting does not require any warm-up time as fluorescent and compact fluorescent lighting do. LEDs come on at full brightness with no warm-up period. Even as the temperature drops, LEDs remain instant on/off lighting. LEDs do not radiate heat. Unlike traditional light bulbs, LEDs do not release or radiate heat, instead they conduct heat. As a result they must be manufactured with a heat sink (these are the fins that are seen on some LEDs). The fins act to increase the surface area and disperse the heat away from the diodes and to the outside of the bulb. These heat sinks can be anything from large fins to smaller dimples, smooth sides or even fans, all of which allow the excess heat to be displaced. shows an example of a heat sink.

LEDs are cold-loving lighting. Unlike other lighting types, LEDs are cold loving and well suited to being out in colder areas. As the temperature drops from 24°C to -59°C, the luminous efficacy of the bulbs increases, and the light output from the bulbs can increase by 20%. LEDs are a type of directional lighting. Since LEDs produce light from a chip, the light radiates from one point and lenses are added to focus the light into the desired beam pattern. Lighting layout and equipment selection is critical to achieve the desired light levels and coverage at bird level. LEDs can produce light that is spot specific or in a side-to-side or end-to-end orientation. LEDs can be produced in a variety of colors. LEDs allow bulb manufacturers to produce light in specific Kelvin range for targeted uses. The color of light produced by the bulb can be changed by altering the number and type of individual light-emitting diodes used in the bulb.

LEDs are dimmable. Some LEDs are dimmable, and that function adds cost to the manufacturing process. Standard dimmers previously used for other lighting types often do not work with LED lighting. These results in flicker, flashes, jumps, dead travel and a change in color temperature when trying to dim lights to low levels. Install new LED dimmers made specifically for LED lights and the lighting application. Check with the dimmer (driver) or bulb manufacturer for compatibility. LED systems can now be remotely controlled for dimming, color turning and operation run times. Lighting is a major expense for poultry farms, as it adds up to 50% of the annual energy consumption. LEDs can reduce the energy usage as they consume 76%-83% less energy than comparable incandescent or halogen bulbs. Remember, higher wattage does not necessarily mean greater brightness, as a 10W LED has a lumen output comparable to a 60W incandescent (consult the lumen value for brightness). Since LEDs are a relatively new and developing technology, it is important to research prior to purchasie LED bulbs. Make sure the bulbs contain a safety rating from either Underwriters Laboratories Inc. (UL), Canadian Standards Association (CSA) or have a recognized certification mark. The initial cost of LEDs may be high but with a short payback time due to energy savings and possible rebates and incentives offered by some local utilities, the long-term savings are significant. Switching to LEDs can result in overall increased revenue because of the lower energy costs.

Objectives

- To know the effect of LED light on the growth performance and feed intake of broiler chicken
- To know the effect of LED light on FCR of broiler chicken
- To know the effect of LED light on flock uniformity of broiler chicken

CHAPTER 2

REVIEW OF LITERATURE

It is very important to review the past research works which are related to the proposed study before conducting any type of experiment. The past research works related to the experimented has been reviewed to conduct the experiment properly. A total about 50 literature were reviewed to identify the background, drawbacks and prospects of research, understand previous findings and to answer the research status of this field. To undertake the present study, the following literatures were reviewed which were performed elsewhere in the world and relevant to the present research work.

Proper management practices are crucial to improving the efficiency, output, and welfare of commercial poultry operations. While there has been considerable research on feed, temperature, litter, housing, biosecurity, and light periods, there has been relatively little investigation on the best light source to use. Different light spectrums have been shown to affect bird behavior (Sultana *et al*., 2013) and even growth (Cao *et al*., 2008), so a proper understanding of the effects of different types of light on poultry is essential to the industry. As new technology becomes available, it must be tested to discover the positive and negative effects of its implementation. Light emitting diodes (LEDs) have already been shown to be superior to other light sources in terms of energy savings, durability, and longevity (*Benson et al*., 2013; Watkins, 2014), but before LEDs can be used in a commercial setting, it must be shown that there are no detrimental effects on the birds.

2.1 Effect of LED light on poultry

Accroding to mendes *et al*. (2013), the broiler is a photosensitive animal which can have its behavior and welfare affected by the illumination of the environment. The perception of light by this species occurs by direct sensitization of the retina, a specialized region within the eyeball capable of forming images and distinguishing colors, which allows its interaction with the environment, as well as mediating the effects of light on growth and behavior.

Rathinman and kuenzel, (2005) conducted an experiment to the retina of the broiler is sensitive to light of wavelength (λ), in the approximate interval of λ_{min} = 360 nm to λ_{max} = 700 nm. (Wilson and Lindstrom, 2011). In association, another form of light perception by broilers occurs through the photo stimulation of deep regions of the brain, which cover the hypothalamus and the pineal gland), through the red light with $\lambda > 700nm$, which crosses the skull (Baxter *et al*., 2014). Melatonin is a hormone synthesized by the pineal gland, retina and gastrointestinal tract, whose main function is to determine the periodicity of food intake, as well as to induce behaviors associated with the night-day cycle (Huang *et al*. 2013). In its turn, according to (rozenboim *et al.,* 2012), the hypothalamus acts on physiological processes such as homeostasis and reproduction.

The use of light-emitting diode (LED) lamps stands out in poultry farming because it presents energy saving and provides viability of the breeding process advantages attributed compared to other lamps (fluorescent and incandescent) include energy efficiency, long shelf life, resistance to humidity, availability of wide wavelengths (light intensities) (Mendes *et al*., 2013, Cao *et al*., 2012) and the low cost of demonization in relation to fluorescent lamps. Researchers have studied the effect of different luminous intensities in poultry, either in egg laying (Nunes *et al*., 2013 Borille *et al*., 2013), such as in meat production (Olanrewaju *et al*., 2006, Deep *et al*., 2012).

Currently, LED use in broiler production has demonstrated high luminous efficiency, less power consumption, and longer service life when compared to incandescent and fluorescent lamps (Cao *et al*., 2012). Evaluation results of different LED colors for artificial lighting system in poultry production and their physiological and production effects are found in literature (Xie *et al*., 2009; Zhang *et al*., 2012; Mendas *et al*., 2013). According to Mendes *et al*. (2010) quality, intensity, photoperiod, and light color may interfere with bird behavior and development. Photosensitive parts of bird brain connected to pineal gland are stimulated by light that reaches the retina receptors; and, therefore, are influenced by environment light (JIN *et al*., 2010).

The artificial lighting used in poultry farming is mostly an adaptation of technology available to humans and there is little information on the effects of the use of poultry lamps on the productivity of the broilers. Thus, the objective was to evaluate the thermo-luminous environment and productive performance of broiler lit by LED tubes in commercial conditions. The objective of this research was to evaluate broiler performance and carcass yield submitted to different LED colors compared to fluorescent lamps.

2.2 Effects of color of light on preferences, performance and welfare in broilers

According to Manser *et al.,* (1996) Light is a central environmental factor in broiler production. Light affects growth rate, animal welfare, and production economy. There are 4 important main features of light: light intensity, photoperiod, light source, and spectrum of light. Research on the effect of light intensity on broiler behavior, welfare, and production started in the early 1960s and our understanding of this topic is progressing (Deep *et al*., 2013). Likewise, lighting programs in broiler houses have been thoroughly investigated, especially during the last 20 yr (Lewis *et al*., 2007). Some research has been put into the effect of different light sources (e.g. Lewis and Morris, 2000; D'Eath and Stone, 1999; Kristensen *et al*., 2007), but as new light sources are developed there is a continued need for research into this area. Finally, less attention has been addressed at the effect of the spectrum of light, and knowledge about this subject is incomplete .

Accroding to (Prescott *et al* .,2003) The color of light is determined by the various outputs from the different wavelengths in the visible spectrum. White light contains all the wavelengths of the visible spectrum, but it differs in color temperature depending on the spectral characteristics, i.e., the power emitted from the different wavelengths. Color temperature is thus an indication of the color appearance of white light, with warmer colors having lower temperatures.Poultry, unlike humans, are also able to detect UV-A light, which lies immediately below the spectrum of light visible for humans (Wortel *et al.,* 1987).

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Presently, the light source used in broiler houses is mainly fluorescent lighting. With the expected continued increase in energy prices, an interest has grown to use less energy consuming light sources. Light-emitting diodes (LED) are energy saving. They are more efficient, durable, and retain the light intensity for considerable longer periods (DOE, 2009; Khan and Abas, 2011). The first LEDs developed were monochromatic; they had a very narrow spectrum so that the resulting color appeared different from white. Recently, LEDs emitting white light with a range of color temperatures have been developed.

Light is important for poultry as they are day-active species. Most of their behavior is mediated by vision [for a review see (Collins *et al*., 2011)] and they have a better vision in bright than in dim light (King-Smith, 1971). Most research into the effects of color of light on behavior, welfare, and performance has been done on monochromatic light, whereas research into white light with different color temperatures is sparse. A preference for monochromatic blue light has been found in broilers reared in green, red, and white light, whereas those reared in blue light preferred green light (Prayitno *et al*., 1997). (Xie *et al*.,2008) suggested that blue light may play a role in alleviating stress response in broilers due to reduction in the level of serum IL-1β. Blue and green light have been found to have a positive effect on growth in broilers (Rozenboim *et al*., 1999, 2004a).

Thus, previous work indicates that using monochromatic blue light may potentially be beneficial to welfare and performance in broilers. However, it has been speculated whether important visual signals are lost in artificial light lacking or being low on parts of the spectrum visible for poultry, e.g., monochromatic light (Prescott *et al*., 2003). To avoid that, light containing emissions from the entire visible spectrum should be used in broiler houses. In the present studies, we therefore examined how LED lighting with power emissions from the full spectrum visible to poultry (although not the UV-A spectrum), but with different color temperatures, affects preference, behavior, welfare, and performance of broilers. As (Rozenboim *et al*.,1999, 2004a) found improved growth in blue and green light we found it essential to investigate the effect of the different light treatments on important welfare indicators, i.e., leg problems and dermatitis, as the extent of these welfare problems is well-known to increase with increased growth (Bessei, 2006). We used 2 color temperatures: 4,100 and 6,065K. The 4,100K is specified as neutral-white, and it is close to the color temperature of the light sources typically used in Danish broiler houses. The color temperature 6,065K is specified as cold-white, as it contains a relative higher power emission from the shorter wavelengths, including those from the blue part of the spectrum, as compared to the longer wavelengths of the spectrum. The 6,065K was chosen as it resembles the color temperature of natural daylight on an overcast day in the tropics and, therefore, seems to be the natural choice of an ancestor of the jungle fowl.

In the first study, we hypothesized that broilers prefer a color temperature resembling that of natural light and therefore would prefer the 6,065K over 4,100K. In the second study, we hypothesized that broilers perform better at a cold-white color temperature (6,065K) compared to a neutral-white color temperature (4,100K) due to the relative higher power emission from the blue part of the spectrum. We hypothesized that the expected improved performance in 6,065K would result in increased occurrence of lameness and dermatitis. The aims of the present 2 studies were therefore to examine the preference for and behavior of broilers in LED color temperatures 4,100 and 6,065K, and effects of LED color temperature 4,100 and 6,065K on performance and welfare.

2.3 Effect of color LED light on broiler chicken

The effect of colored lighting on poultry has been studied over the last 30 years and increasingly so in recent years. In the commercial market, many kinds of light have been introduced and LED lights are much more energy efficient and provide adequate illumination. Thus, conventional light based systems have been banned from 2012 and gradually replaced with the LED light in the Republic of Korea. Therefore, it is necessary to find out which light colour affects the chickens normal behavior. In broiler behavior observation trials, most researchers assessed different light intensities (D'Eath *et al.,* 1999), light sources (Vandenbert and Widowski, 2000), light colours (Prayitno *et al.,* 1997) and flickering frequencies (Widowski and Duncan, 1996). Lewis and Morris, (2000) mentioned that the light colour has varying stimulatory effects on the retina and affects behavior and growth. Some authors believe that poultry behaviour depends largely on the length of the light waves perceived by birds (maddocks *et al.,*2002). In the case of the broiler, red light increases the activity as compared with blue and green lights (Prayitno *et al.,* 1997). Therefore, in modern broiler husbandry, the use of coloured lighting systems is increasing used to enhance performance. Meanwhile, most researcher have focussed on the performance, but relatively little attention has been given to the behaviour and well being of the broiler chicken (Manser, 1996; Prescott *et al.,* 2003).

Consequently, broiler behaviour studies have found that the time spent inactive increases with the age of the chicken (Newberry *et al.,* 1988; Weeks *et al.,* 2000; Cornetto and Estevez, 2001; Bizeray *et al.,* 2002; Kristensen *et al.,* 2006). On the other hand, duration of tonic immobility has been used as a measurement for evaluating fear behaviour and may be used as criteria for measuring well-being and levels of stress in chickens (Yalcin *et al.,* 2003).

However, there is a lack of studies on the effect of LED mono and mixed colour on the behaviour of broiler. Therefore, Experiment 1 was undertaken to discover the effect of mono and mixed light colour on the behaviour of broiler, and Experiment 2, was designed to investigate the behaviour of broilers of different ages reared under six light sources to assess their behavior and fear responses.

2.4 Effect of LED color light on broiler growth and other behavior

Artificial lighting is a tool used in poultry production and it aims to improve food and water intake and consequent growth, and hence flock economic feasibility (Mendas *et al.,* 2010). Poultry light programs are prepared in accordance with bird metabolism changes at different ages, and they vary according to final weight required by the market. One of the biggest challenges in broiler production is related to power consumption, which substantially increases production cost (Yanagi junior *et al.,* 2011; Pereira *et al.,* 2012). Thus, the ideal light program provides maximum production and reduces energy expenses.

Several factors must be taken into consideration when assessing a lighting program for birds, namely light period, light spectrum, and light intensity. Light period is the most heavily researched aspect of bird lighting as it is crucial for proper layer management (Rozenboim *et al.,*1999) and can increase growth efficiency in broilers (Lewis *et al.,* 2000). Fear responses have also been shown to be affected by changes in light period, with birds under a 16L:8D lighting schedule showing less fear than birds under continuous light (Bayram and Ozkan *et al.,* 2010).

Light spectrum refers to the amalgamation of different powered wavelengths of electromagnetic radiation emitted from a light source, and for this paper is limited to the range visible to poultry from 350 to 700 nm. The visual range of poultry differs from that of a human in several ways, the most striking being inclusion of the ultraviolet (UV) range due to the addition of a fourth type of single-cone photoreceptor (Osorio *et al.,* 2004; Prescott and Wathes, 1999). Spectral sensitivity is not even across the spectrum, and birds have been shown to have maximum visual sensitivity at 415 nm, 455 nm, 508 nm, and 571 nm (Prescott *et al.,* 2003).

Certain behaviors have been shown to be frequency dependent through trials that exposed birds to specific frequencies. Birds were shown to spend more time sitting or standing in place under short wavelengths (blue/green), and exhibited more locomotion under longer (red/yellow) wavelengths (Sultana *et al*., 2013). The addition of supplemental UV light has been shown to increase mating behaviors, egg output, and locomotion over control birds lit with normal fluorescent lights (Jones *et al.,* 1983; Lewis *et al.,*2007), as well as decreasing the incidence of rickets and tibial dyschondroplasia in developing birds (Edwards, 2003). The spectral output of available light sources can vary drastically: from a direct increase from blue to red in incandescents, to the many narrow peaks seen in compact fluorescent lamps (CFLs), and finally the 2 or 3 gradual peaks seen in LEDs (Morrison *et al.,*2013). Light intensity is related closely to light spectrum, and results in several difficulties in correctly measuring intensity. Since almost all light meters are designed for human sensitivity, they may not be giving a correct approximation of how the bird perceives the light (Prescott and Wathes, 1999).

If the peaks in the spectrum do not match the visual sensitivity of the birds, perceived intensity may be much lower than what light meters indicate. Conversely, what a human perceives as a low intensity may be much more intense to a bird with the inclusion of UV light. While there have been many studies comparing intensity with the same bulb type, it is more difficult to compare light sources with varying spectra. More research is needed to create an accurate model of poultry vision and intensity perception.

Stress parameters such as heterophil/lymphocyte ratios (Onbasilar *et al.,* 2014), immune function (Xie *et al.,* 2008), and physical asymmetry (Campo *et al.,* 1994) have been previously shown to be affected by changes in lighting programs. Stress occurs when an animal experiences changes in the environment that stimulate responses aimed at reestablishing the homeostatic condition (Mumma *et al.,* 1996). It is not inherently negative (Sherwin *et al.,* 2010), but stress is well documented to divert energy away from normal biological functions and interfere with reproduction, immune function, and development (Mobarkey *et al.,*2010). There are several measures of stress used in poultry: physical asymmetry, heterophil/lymphocyte (H/L) ratio, and corticosterone (CORT) concentration. Physical asymmetry is simply a comparison of bilateral structures on a bird; structures on the left and right side of the bird are measured and a larger difference indicates greater asymmetry (Campo *et al.*, 2008).

Physical asymmetry has been strongly correlated to stress in many studies, with greater asymmetry indicating a stronger perception of stress (Graham *et al.,* 1993; Knierim *et al.,* 2007; Archer and Mench, 2013). Heterophil/lymphocyte ratio is another measure of stress in poultry, and involves counting the 2 types of blood cells and comparing their ratio. Gross and Siegel (1983) showed that the number of lymphocytes in chicken blood samples decreased and the number of heterophils increased in response to stressors, but that the ratio of the 2 was a more reliable indicator than individual cell counts. It has been seen that H/L ratio correlates to other stress measures quite well when measuring constantly lit versus 14L:10D scheduled birds (Chen Y *et al.*, 2007). But unlike other stress measures, H/L ratio is not significantly different across different breeds (Campo *et al.*, 2008). Finally, CORT has been shown to be a reliable indicator of stress in poultry (Archer and Mench, 2013). Corticosterone is a stress hormone that is produced in chickens during lighted periods and may interact with melatonin to modify the stress response, though the mechanism is not fully understood (Özkan *et al.*, 2012a,b). Lower CORT concentrations correlate with lower bird stress.

Fear has also been shown to be affected by lighting, with some studies showing that different spectra impact fear responses differently (Sultana *et al.*, 2013). There are several ways of studying fear in poultry, and fear can be tied to differences in stress levels and performance. Since poultry are prey animals, fear of predation and predator avoidance are major components of a bird's fear response. Ratner (1967) defines 4 such behaviors as a progression from freezing, to fleeing, to fighting, and finally tonic immobility.

The first component, freezing, occurs when an animal sees a distant predator and ceases all movement in an attempt to avoid detection. An animal may still freeze if spotted, relying on other moving objects to distract the predator (Suarez and Gallup, 1983). Fleeing occurs when the predator approaches to a certain distance, known as the flight distance. Once the predator enters the flight distance, the prey will actively attempt to escape and avoid the predator (Dwyer, 2004). If the prey is unable to avoid capture by fleeing, it will attempt to struggle and break free from the predator (Ratner, 1967).

This is measured in poultry through the use of an inversion test described below. Since inversion is used in capture and transport of commercial poultry, Newberry and Blair (1993) state that it is a practical measure of fear for birds used in commercial production. Finally, if the animal is unable to escape, it will enter in to tonic immobility (TI). This response is characterized by a sustained period of non-responsiveness brought about by physical restraint (Maser *et al.*, 1973; Jones, 1983), and is considered to be the final stage of fear response in wild animals (Ratner, 1967). The length of time a bird will remain under TI in a controlled environment has been observed to be reduced in birds housed under distinct day/night cycles when compared to birds exposed to constant or near-constant light (Campo and Davila, 2002; Campo *et al.,* 2008; Onbasilar *et al.,* 2014).

Since there has been limited research on the behavioral and physical effects of modern light sources on poultry, an experiment was conducted to elucidate any differences between 3 types of light source. The objective of this study was to evaluate how 2 brands of LED bulbs and an alternative CFL blub that are available to the poultry industry, each of which produces a different spectral output, affect production and welfare of broiler chickens. It also compared several stress, fear, and welfare assessments to best determine how changes in lighting affect bird behavior, performance, and efficiency. It is hypothesized that the use of LEDs in place of CFLs will not result in any negative effects on behavior or production, and will act to reduce stress and fear responses in growing and adult birds.

In association, another form of light perception by broilers occurs through the photostimulation of deep regions of the brain, which cover the hypothalamus and the pineal gland (rathinman & kuenzel, 2005), through the red light with $\lambda > 700$ nm, which crosses the skull (Baxter *et al.,* 2014). Melatonin is a hormone synthesized by the pineal gland, retina and gastrointestinal tract, whose main function is to determine the periodicity of food intake, as well as to induce behaviors associated with the night-day cycle (Huang *et al.* 2013). In its turn, according to (rozenboim *et al*.2012), the hypothalamus acts on physiological processes such as homeostasis and reproduction.

(Paixao *et al.* 2011) studied two light sources (fluorescent and white LED) and observed no difference in broiler performance. Cao et al. (2008) evaluated four LED colors (white, red, blue and green) in poultry production and found different results. Those results indicated that birds kept under blue light showed higher body weight at 21-48 day growth. (Rozembolm *et al.* 1999) also found higher body weight in broilers exposed to blue and green light at 34 day growth, but found no difference in feed conversion throughout total rearing period.

2.5 Comparison of LED light bulbs to incandescent bulbs and their effects on broiler chicken

Several factors must be taken into consideration when assessing a lighting program for birds, namely light period, light spectrum, and light intensity. Light period is the most heavily researched aspect of bird lighting as it is crucial for proper layer management (Rozenboim *et al.*, 2004) and can increase growth efficiency in broilers (Lewis *et al.*, 2010). Fear responses have also been shown to be affected by changes in light period, with birds under a 16L:8D lighting schedule showing less fear than birds under continuous light (Bayram and Ozkan, 2010).

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Since there has been limited research on the behavioral and physical effects of modern light sources on poultry, an experiment was conducted to elucidate any differences between 3 types of light source. The objective of this study was to evaluate how 2 brands of LED bulbs and an alternative CFL blub that are available to the poultry industry, each of which produces a different spectral output, affect production and welfare of broiler chickens. It also compared several stress, fear, and welfare assessments to best determine how changes in lighting affect bird behavior, performance, and efficiency. It is hypothesized that the use of LEDs in place of CFLs will not result in any negative effects on behavior or production, and will act to reduce stress and fear responses in growing and adult bird.

CHAPTER 3

MATERIALS AND METHODS

3.1 Statement of the experiment

The experiment was conducted at the SAU poultry farm, Sher-e-Bangla Agricultural University, Dhaka-1207, during the period of 21-02-2019 to 21-032019 on Cobb 500 broilers. The research was carried out with an aim to investigat the effects of LED light on performance as well as growth of broilers. A complete randomized experimental design with subplots will be applied, with 3 treatments of five replicates. Performance was observed on daily basis. Body weight and feed intake recorded on day 7, 14, 21 and 28.

3.2 Collection of experimental chicks and tools

Broiler of one day old chicks (DOC) was collected from kazi hatchery. The finally selected 150 chicks were allowed to acclimatize for 28 days in the experimental shed. The body weights of assigned chickens were taken with digital weight machine and the results were recorded. During acclimatization the chicken were maintained similar environment and with deep litter system under optimum condition of brooding management. LED light collected from local market.

3.3 Experimental design

The experiment was conducted in a completely Randomized Design (CRD). These chicks were randomly divided into 3 treatments with five replicates. Birds in all treatment will rear under standard lighting program, and will be fed a corn and soybean meal-based standard balance diet. The following lighting treatments will be used-

- T0= 40W incandescent light
- T1= Green LED light
- T2= Red LED light

3.4 Collection of feed and feeding system

Used feed were purchased from a feed shop. The experimental birds were fed adlibitum. The experimental rations consisted of broiler starter and broiler finisher. Broiler starter feed were used day 1 to day 14 and broiler grower feed was used day 15 to day 28. Purchased feed bag open only feeding time and rest part of day bag was tightly closed with a rope. After complete using of one bag, another bag is open for feeding. Nutritional value of purchased feed as shown below-

Table 3.1: Name and minimum percentage of ingredients present in starter and grower ration

Type of Feed	Broiler Starter	Broiler Grower
Moisture % (Maximum)	12	12
CP % (Minimum)	21	20
CF % (Maximum)	5	5
Calcium % (Minimum)	1	0.95
Phosphorus % (Minimum)	0.45	0.45
Methionine (Minimum)	0.48	0.45
Lysine (Minimum)	1.15	1.05
Energy (kilocalorie/Kg)	2950	3000

Source: Cobb500 Broiler Management Guide, 2016

3.5 Management of LED

Light is very much important for broiler performance. Color LED bulb was used for lighting. 24 hour lighting per day was provided throughout the experimental period. During early stage of age, the bulbs were hanged just above the chick's level at the center of pen. In the course of the trial, the temperature was gradually reduced up to the end of trial. For optimum ventilation the curtain management was done properly.

The farm was divided in 3 chamber. Each chamber is used for different color light. In each chamber 5 blub is used for lighting.

3.6 Management practice

3.6.1 Preparation of house

The farm was prepared by using different type of cleaning process. The house (ceiling, wall, floor and wire net) was properly brushed with the help of a broom and washed by forced water, then floor of the house was disinfected to make as possible as free from different pathogenic surface microorganisms by using phenyl solution and the room was left vacant for 7 days. Ceiling wall and wire net were thoroughly disinfected by spraying TH4+ (quaternary ammonium chloride, Glutardialdehyde, Pine oil & Tarpine oil) 1ml/L water and kept free to dry up properly. At the same time, all feeder, plastic buckets, waterer and other necessary equipment's were also properly cleaned, washed and disinfected with TH4+ (4ml/L), subsequently died and left them empty for one week before arrival of the chicks. Fresh and dried rice husk litter material was spread on the floor.

3.6.2 Distribution of chicks

Chicks were supplied with 5% glucose solution and vitamin C (1g/3L) to minimize stress for transportation after arrival in the experimental house. After seven days' chicks were distributed randomly to individual pan (part). The experimental chicks were kept in separate pens each measuring 3 x 2 square feet according to treatment where one feeder and one waterer were placed.

3.6.3 Temperature and ventilation

Temperature and ventilation is very much important for broiler performance. Electric bulb was used for light and temperature control. 24 hour lighting per day was provided throughout the experimental period. During early stage of age, the bulbs were hanged just above the chick's level at the center of pen. The brooding temperature was maintained 34° C for the 1^{st} week. In the course of the trial, the temperature was gradually reduced up to the end of trial. For optimum ventilation the curtain management was done properly.

3.6.4 Feed and water supply

At first day mash feed was supplied on clean newspaper, second and from second day feed was given feeder. Water was supply in waterer from the first day. Feed and water was supply halic to the experimental chicks.

3.6.5 Vaccination

In this experiment used newcastle disease (ND) and infectious bursal disease (IBD) vaccine for all of the experimental chicks as per recommendation of manufacturer. Vaccination schedule and followed during the experimental period is given below-

Table 3.2: Vaccination schedule for experimental broiler

Age	Disease	Route of administration and dose
5 days	Newcastle (ND)	One drop in one eye
10 days	Gumboro (IBD)	One drop in one eye
17 days	Gumboro (IBD)	One drop in one eye
22 days	Newcastle (ND)	One drop in one eye

3.6.6 Biosecurity

Proper biosecurity measures were taken during the experimental period. The equipments were made clean and disinfectant. Footbath which contains TH4+ was placed at the entrance of the house. Apron, musk and hand gloves were used inside the house during working. Strict bio-security program was maintained during the whole experimental period.

3.7 Data Collection and analysis

The experiment will be carried out by collecting data from 5 replications. Following information will be included- body weight, egg production, egg weight, body weight gain, behavior. All the data subjected to ANOVA table using general linear model procedure of SAS software.

PICTURE GALLERY

Fig 1: Brooding of chicks.

Fig 2: Vaccination of chicks.

Fig 3: Red LED treatment.

Fig 4: Feeding system.

Fig 5: Housing system.

Fig 6: Feed for grower.

CHAPTER 4

RESULTS AND DISCUSSION

4. Production performances of broiler chicken

4.1 Body weight

The data presented in table 3 showed that the effect of treatments on body weight (g per broiler chicken) was at the 1% level of significant at 4th week of age. Final body weight of broiler chicken observed in 4th week of age and the mean value and standard deviation of body weight of treatment group T1, T2 and T0 were 1535.50^{b}±31.57, 1540.48^{a}±26.95, 1527.76^{c}±16.89 respectively. The highest body weight was found in T2 (1540.48^{a}±26.95) group and lowest was T0 (1527.76^{c}±16.89) group. However, the relative body weight (g) of broiler chickens in 1st week in the treatment group T1, T2 and T0 were 198.59±5.33, 199.98±1.79, 198.50±2.83 respectively. The overall growth performance of broiler in 1st week was almost same. In addition, 2nd and 3rd week of age body weight were almost same in all treatment. These results were in agreement with those obtained by(J. Cao *et al.* 2008), who found that there was no adverse effect of color LED lights on final body weight. (Borille R *et al.* 2013) was also resembled that color LED lights have no effects on poultry growth performance. The enhancement in body weight of T2 group might be due to using green LED light of the birds flock.

Table 3: Effects of color LED light on body weight (BW) (g/bird) of broiler chickens at different week.

	Body weight (g)/bird			
Treatment	**1st week**	**2nd week**	**3rd week**	**4th week**
T1 (red light)	198.59±5.33	559.84±14.47	950.12±8.90	1535.50^{b}±31.57
T2 (green light)	199.98±1.79	530.80±10.16	944.96±11.91	1540.48^{a}±26.95
T0 (white light)	198.50±2.83	511.94±9.70	950.75±32.29	1527.76^{c}±16.89
SEM	0.887	5.956	4.955	6.341
Level of sig.	NS	NS	NS	**

Here, g = gram, Values are mean ± SD, SEM= standard error mean.
NS = Not significant (P>0.05)
** = Significant at 1% level of probability (P<0.01)…..

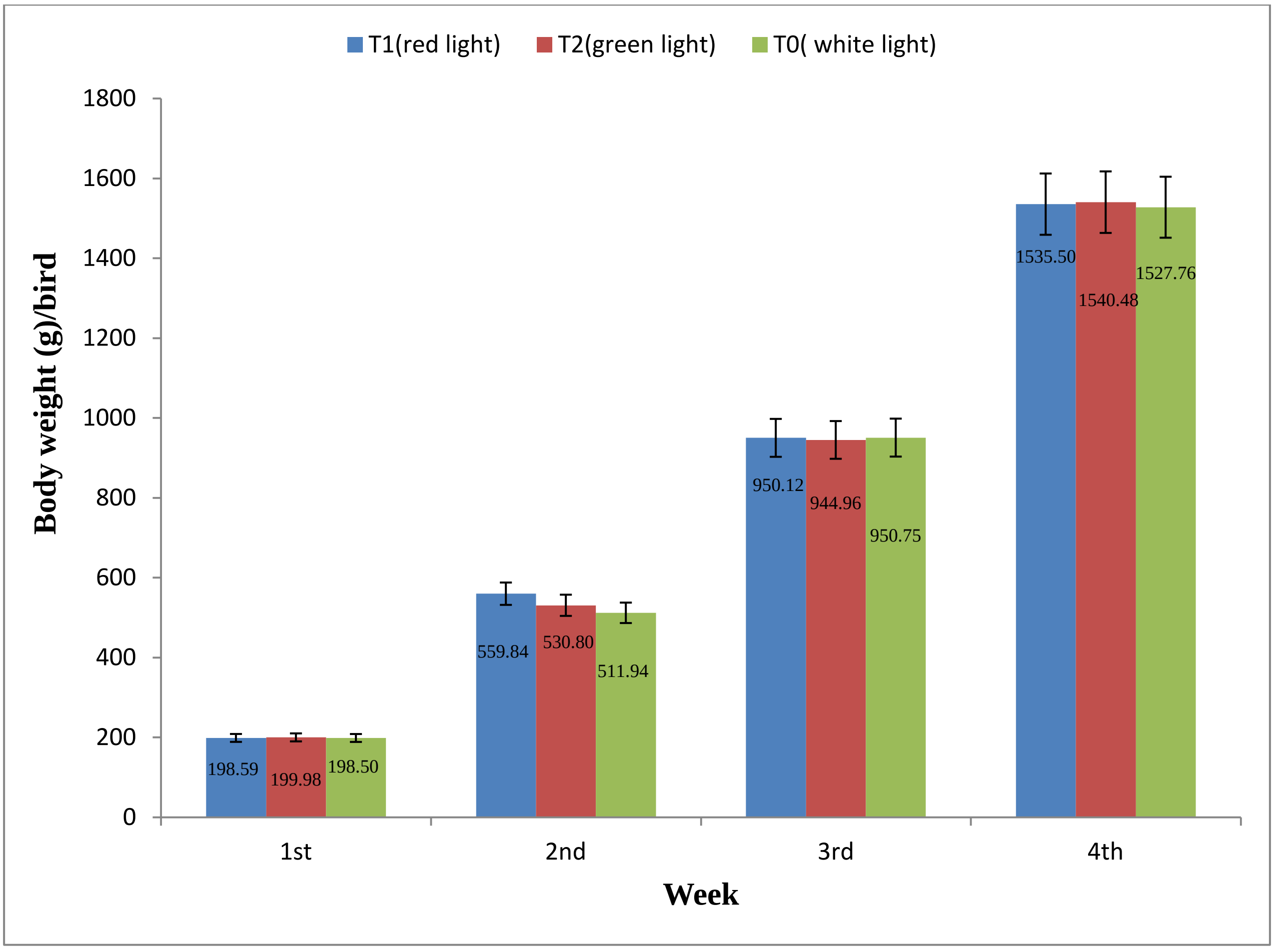

Fig 7: Effects of color LED light on body weight (BW) (g/bird) of broiler chickens at different week.

4.2 Feed consumption (FC)

Different treatment groups (Table 4) showed that significant ($P<0.05$) in weekly FC of broiler chicken. T2 (green light) group consumed lower amount of feed ($646.16^{b}\pm43.29$) and showed 5% level of significant in 3rd week of age. Therefore, weekly FC of all other treatment groups were almost similar. These results were in agreement with those of previous researchers (Borille R *et al.*,2013), who recorded no significant ($P>0.05$) effects of LED light on performance parameters. According to (Rozenboim *et al.*, 1999), the effect of lighting on feed intake is associated to birds' locomotion activity, which is very reduced during dark periods. As movement is reduced, so is energy expenditure, resulting in better feed efficiency and lower feed intake. Some authors (Edwards *et al.*, 2003) observed influence of lighting on feed intake only when artificial lighting programs were used, which is not the case of the present study. In contrast, other researchers (J. Cao *et al*. 2008) reported that sometime green light significantly (P<0.05) improved Feed consumption (FC) of broiler chickens.

In the present study, the effects of LED light on broiler performance parameters including total feed consumption were not influenced by the LED light colour. These results are in agreement with those of previous researchers (Sultana *et al*., 2013) who recorded the feeding behaviour was not influenced by the light colour in the morning but was influenced in the afternoon. In the present results, monochromatic G, R and mix of RY light colour did stimulate the feeding behaviour of broiler. On the other hand, drinking behaviour was not significantly affected by the light colour.

Table 4: Effects of color LED light on feed consumption (g/bird) of broiler chickens at different week.

Treatment	Feed consumption (g)/bird				
	1^{st} week	2^{nd} week	3^{rd} week	4^{th} week	Total
T1 (red light)	237.00±0.00	435.04±11.09	654.06^{ab}±35.39	1039.27±1.63	2369.37±50.27
T2 (green light)	237.00±0.00	440.12±17.06	646.16^{b}±43.29	1022.00±40.25	2333.28±109.77
T0(white light)	237.00±0.00	435.04±7.00	661.94^{a}±25.39	1039.27±1.63	2373.25±37.83
SEM	0.000	3.038	8.648	5.974	18.112
Level of Sig.	NS	NS	*	NS	NS

Here, g = gram, Values are Mean ± SD, SEM= Standard error mean.

NS = Not significant (P>0.05)

* = Significant at 5% level of probability (P<0.05)

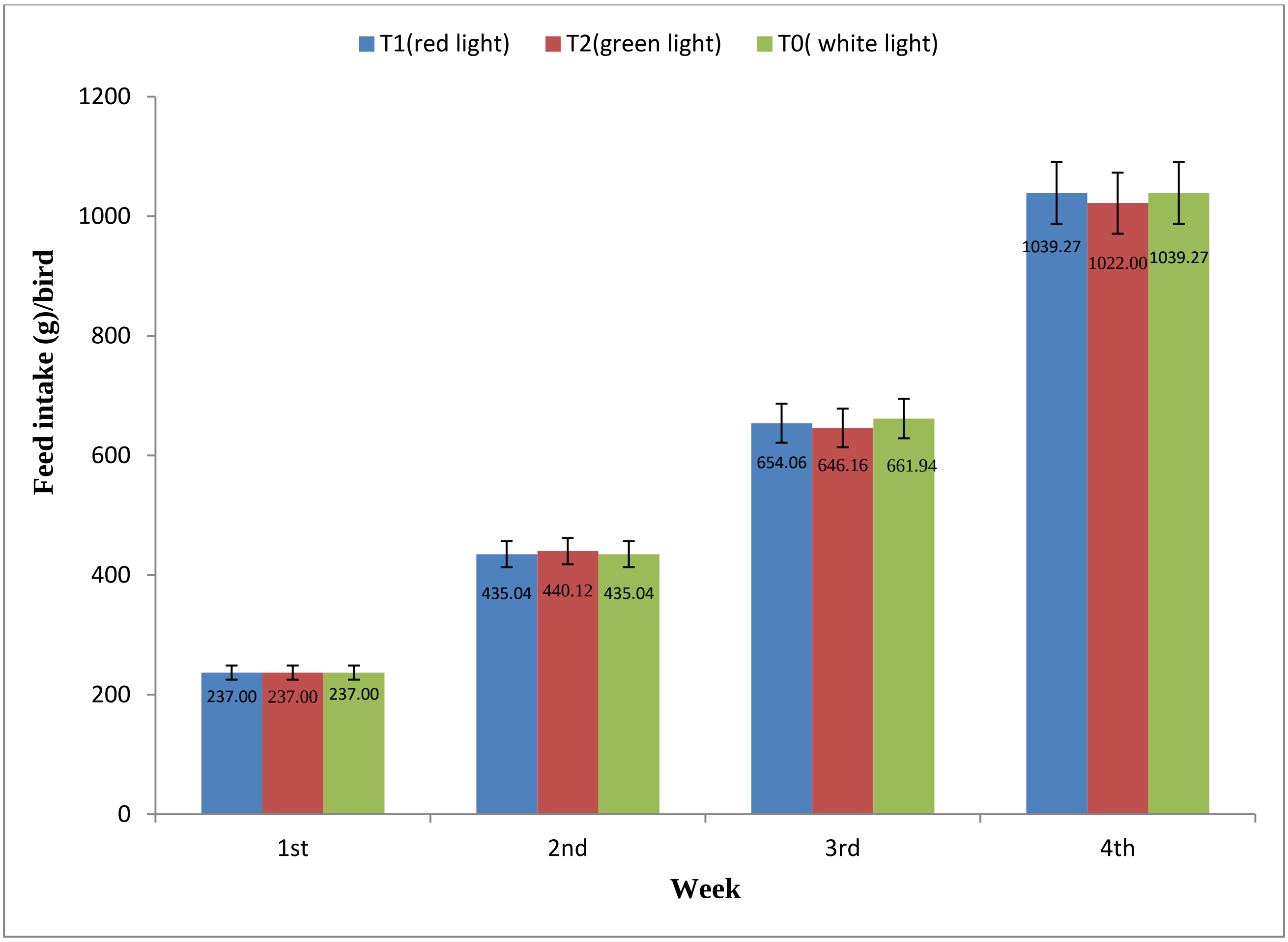

Fig 8: Effects of color LED light on feed consumption (g/bird) of broiler chickens at different week.

4.3 Feed conversion ratio (FCR)

The mean body FCR of broiler chicks at the end of 4th week in T1, T2 and T0 groups were 1.54±0.04, 1.51±0.05 and 1.55±0.02 respectively. The FCR of different groups showed that there was no significant (P>0.05) increase in groups T1 and T2 compared to control. However, Feed conversion ratio (FCR) was significantly (P<0.05) higher in T0 group (1.31^{a}±0.04) (incandescent) compared to T1 treatment (1.20^{b}±0.04) and T2 (1.25^{ab}±0.06) groups respectively in 2^{nd} week of age.

These results are in agreement with those of previous researchers (Borille *et al*. 2013), who recorded nonsignificant (P>0.05) effects of LED light on FCR parameters. Feed intake and weight gain was not significantly influenced by light sources or periods. This indicated that birds had the same visual sensitivity to all tested light sources, and did not change their feeding behavior as a function of light source.(Paixao *et al.* 2011) verified that the white LED lamp has the same effect of the fluorescent lamp on the productive performance of broilers like feed intake, live weight, feed conversion ratio (FCR), making it viable due to the saving of electric energy. For (Santana *et al.* 2013) LED illumination in different colors and illuminance, when compared to fluorescent light, did not affect growth performance parameters of broilers like weight gain, feed intake and feed conversion ratio (FCR).

Table 5 : Effects of color LED light on FCR of broiler chickens at different week.

	FCR			
Treatment	1^{st} week	2^{nd} week	3^{rd} week	4^{th} week
T1(red light)	1.19±0.03	1.20^{b}±0.04	1.40±0.04	1.54±0.04
T2(green light)	1.19±0.01	1.25^{ab}±0.06	1.39±0.06	1.51±0.05
T0(white light)	1.19±0.02	1.31^{a}±0.04	1.40±0.03	1.55±0.02
SEM	0.005	0.017	0.011	0.010
Level of Sig.	NS	*	NS	NS

Here, FCR= Feed conversion ratio, Values are Mean ± SD, SEM= Standard error mean.

NS = Not significant (P>0.05)

* = Significant at 5% level of probability (P<0.05)

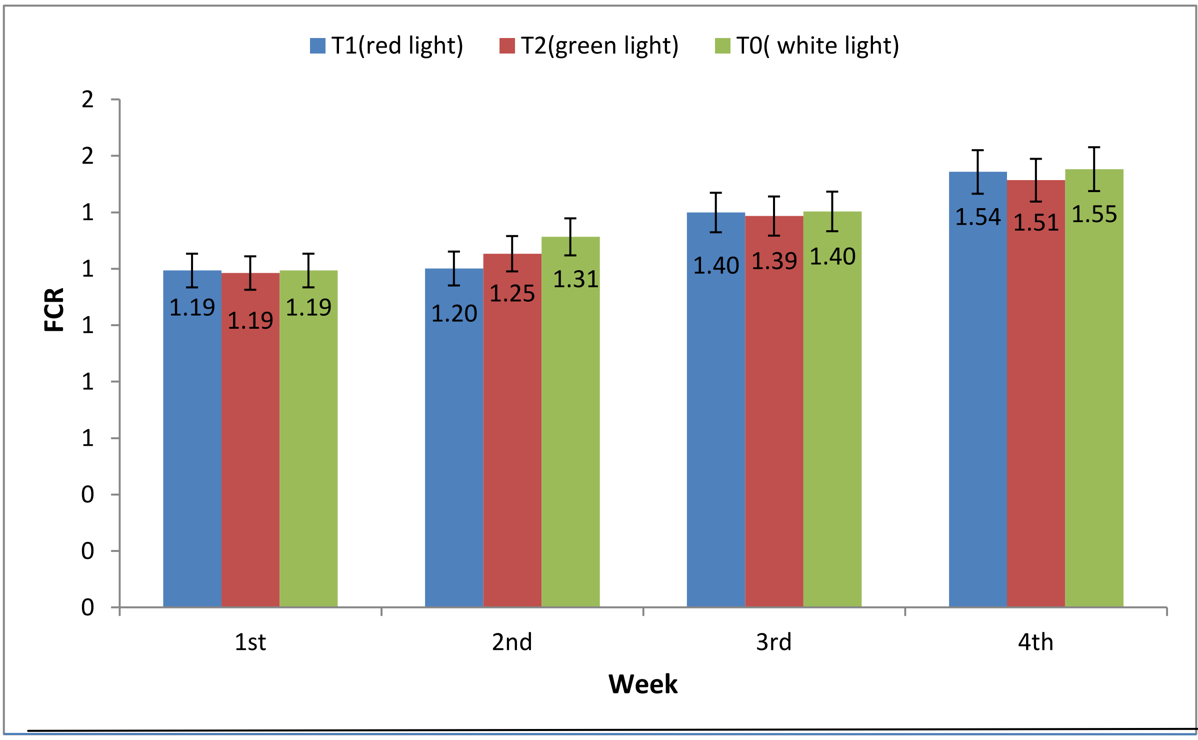

Fig 9: Effects of color LED light on FCR of broiler chickens at different week.

4.4 Uniformity

Effect of color LED light on uniformity (%) of Cobb 500 strain broiler chicken during 28 days of age is summarized in Table 6. The comparative uniformity of broiler chicken in the treatment group T1, T2, and T0 were 84.80^{a}±5.02 (%), 73.40^{b}±6.15 (%), 70.40^{b}±0.89 (%) respectively. The highest value was T1 (84.80^{a}±5.02%) and lowest value was T0 (70.40^{b}±0.89%). The relative uniformity of different groups showed significant (P>0.05) difference among the groups.

In an experiment performed by (Kristensen *et al.* 2006), evaluated the productive parameters of broilers raised in an environment illuminated by two distinct light sources. The results showed that there was a correlation between the uniform growth of the broiler and locomotive performance, but no influence of the ambient light on body weight, feed intake and mortality was observed. They concluded that the two sources of light at different lighting levels did not significantly affect locomotive and production parameters like uniformity. According to Shabiha (Sultana *et al.* 2013) the uniformity (%) of broiler chickens has been previously assessed using monochromatic light, but no studies have been conducted to investigate the effects of LED mono and mixed light colors on broiler chicken. The enhancement in uniformity of T1 group might be due to using red LED light of the birds flock.

Table 6: Effects of color LED light on uniformity of broiler chickens.

Treatment	Uniformity (%)
T1(red light)	84.80[a]±5.02
T2(green light)	73.40[b]±6.15
T0(white light)	70.40[b]±0.89
SEM	1.991
Level of Sig.	**

Here, Values are Mean ± SD, SEM= Standard error mean.

NS = Not significant (P>0.05)

** = Significant at 1% level of probability (P<0.01)

CHAPTER 5

SUMMARY, CONCLUSION AND RECOMMENDATIONS

A total of 28 day-old Cobb-500 broiler chicks were reared in Sher-e-Bangla Agricultural University Poultry Farm, Dhaka. Chicks were divided randomly into 3 experimental groups of 5 replicates (10 chicks with each replication). One of the 3 experimental groups was fed a corn and soybean meal-based standard balance diet. Birds in all treatment will rear under standard lighting program. 24 hour lighting per day was provided throughout the experimental period. Each chamber is used for different color light. In each chamber 5 blub is used for lighting. Light intensity was standardized across all sources of light.

Light is an important environmental factor for birds, allowing not only their vision, but also influencing their physiological responses, such as behavioral and growth. The objective of this experiment was to evaluate the impact of different colors of monochromatic light (LED) sources on broiler. The effects light (LED) were measured. The performance traits viz. body weight, weight gain, feed consumption, FCR, uniformity of broiler on different replication of the treatments was recorded and compared in each group. Body weight and Feed intake recorded on day 7, 14, 21 and 28 of all bird.

The all group showed similar body weight. The weight gain, feed consumption, and FCR followed similar trends with an exception that group T1 have better uniformity then other 2 group.

Under the conditions of the present experiment it was concluded that the replacement of incandescent light bulbs by red and green LEDs does not cause any negative effect on the production of commercial broiler. Weight and other parameters were not negatively influenced by the replacement of incandescent lamps by LEDs of all evaluated colors. The replacement of incandescent lamps by LED light saves electrical energy which will be economic for farmer.

Therefore, it is recommended that green and red colors of LED light source can be used for rearing commercial broiler and the replacement of incandescent lamps by LED light saves electrical energy which will be economic for farmer. However, further research is needed to ensure the usefulness of color LEDs.

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APPENDICES

Appendix 1. Nutrient composition of the ingredients used to formulate experimental diets.

Ingredients	DM (%)	ME(K. Cal/kg)	CP(%)	CF(%)	Ca(%)	P (%)	Lys(%)	Meth(%)	Tryp(%)
Soybean meal	90.0	2710	44.5	7.5	0.3	0.2	2.6	0.8	0.6
Maize	89.5	3309	9.2	2.4	0.3	0.4	0.2	0.12	0.1
DCP					22	17.2			
Soybean oil	100.0	8800							
Protein concentrate	91.6	2860	63.3	8.1	6.4	3.2	3.9	1.8	0.5
Meat and Bone meal	95.5	1044	14.6	2.5	7.0	12.1	0.6	0.2	0.1

Source: Cobb 500 Broiler Management Guide, 2016

Appendix 2. Recorded temperature (0C) and humidity /(%) during experiment.

Age of bird	Temperature (°c)		Humidity (%)	
	Avg. Max	Avg. Min	Avg. Max	Avg. Min
1st week (21.02.19-27.02.19)	32.20	23.98	61.20	45.00
2nd week (28.02.19-06.03.19)	28.34	17.79	78.00	55.00
3rd week (07.03.19-13.03.19)	31.64	21.41	78.00	46.00
4th week (14.03.19-21.03.19)	40.00	41.00	42.00	43.00

Appendix 3. Average live weight, feed intake and FCR of different replication of broiler chicken under different treatment.

Treatment	Replication	Body weight(g)/bird	Avg. body weight(g)	Total feed intake(g) /bird	Avg. total Feed intake(g)	FCR	Avg. FCR
T1(red light)	R1	1515.30		2394.00		1.58	
	R2	1609.50		2391.50		1.48	
	R3	1566.30	1535.50	2394.00	2369.37	1.53	1.54
	R4	1573.50		2387.80		1.51	
	R5	1412.91		2279.56		1.61	
T2 (green light)	R1	1537.90		2393.40		1.56	
	R2	1557.10		2378.50		1.53	
	R3	1565.70	1540.48	2382.10	2333.28	1.52	1.51
	R4	1595.50		2375.10		1.49	
	R5	1446.20		2137.30		1.48	
T0 (white light)	R1	1531.40		2384.20		1.57	
	R2	1516.10		2387.70		1.57	
	R3	1571.20	1527.76	2387.00	2373.25	1.52	1.55
	R4	1545.00		2400.80		1.55	
	R5	1475.10		2306.56		1.56	

Appendix 4. Uniformity of different replication of broiler chicken under different treatment

Treatment	Replication	Uniformity	Avg. Uniformity
	R1	90%	
	R2	90%	
T1 (red light)	R3	90%	78%
	R4	90%	
	R5	64%	
	R1	80%	
	R2	70%	
T2 (green light)	R3	80%	75%
	R4	70%	
	R5	67%	
	R1	80%	
	R2	60%	
T0 (white light)	R3	60%	73%
	R4	70%	
	R5	82%	