

BROILER PREFERENCE FOR LIGHT COLOR AND FEED FORM, AND THE EFFECT OF  
LIGHT ON GROWTH AND PERFORMANCE OF BROILER CHICKS.

by

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## Abstract

Over the decades much has been discovered about the appropriate lighting management strategies for raising commercial meat-type poultry. Our knowledge of light preference, wavelength, intensity, intermittent lighting, and avian spectral sensitivity continues to improve our management strategies. In this work, a total of 5 experiments were conducted.

The first 2 experiments investigated the effects of Light emitting diodes (LED) lights on growth performance of broiler chicks. Broiler chicks were raised under LED lights at different intensities: 5, 10, 15, 20, and 25 lux. A significant linear relationship ( $P < 0.05$ ) was found in experiment 1 between body weight gain and light intensity. In experiment 2, a linear trend was noticed between body weight gain and light intensity. As the light intensity increased, chick weight increased. Feed: gain ratios were not affected by light intensity. The third experiment also examined growth performance using LED lighting as well as the effects of feed form and different lighting intensities upon behavior. The broilers fed a pelleted diet had significantly better performance than those fed crumbles. Under more intense light it was discovered that broilers spend significantly more time ( $P < .05$ ) consuming feed compared to dim light.

The fourth experiment focused on broiler preference for light color, and feed form during feeding. The broilers were offered either pelleted or crumbled feed and served under 4 different light colors: red, white, blue, and green. It was found that broilers statistically preferred pelleted feed, and white lighting, with red being the 2<sup>nd</sup> color choice of preference while green and blue were statistically not chosen.

The fifth experiment focused on chick preference for feed color, when under different light color. One day old chicks were offered dyed feed: red, yellow, blue, green or light brown

(control) under 5 different colors of light: red, yellow, blue, green, and white. It was found that chicks significantly preferred red dyed feed, especially under blue light.

In conclusion, it was found that LED lights can have positive effects on broiler performance. Broilers show a preference for white lighting and pelleted feed. Young chicks show a preference for red dyed feed.

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# Chapter 1 - Literature Review

## Introduction

The effect of lighting on poultry is a topic that has been studied for decades. Wavelength, intensity, photoperiod, type and placement of lighting all play an important part in bird development and performance. Since light bulbs were invented, the primary source of lighting for avians of all types has been incandescent lighting. Over the last 3 decades and increasing dramatically in recent years, different types of lighting have been introduced into houses and poultry barns as well. Modern lights are much more energy efficient and still provide adequate illumination. This has required new research on the entire lighting management system for growing broilers. Three of the most common replacements for the incandescent bulb are fluorescent, metal halide, and high-pressure sodium (Olanrewaju et al, 2006). Meat-type chickens (broilers) have a different set of requirements for lighting than do laying hens, or breeders. Currently broiler chickens are grown under low light conditions, often under green or blue light. This combination effect calms the birds and helps reduce cannibalism as well as improving bird performance. Many studies indicate that broilers raised under blue or green light were heavier than those raised under red or white light (Cao et al. 2008; Rozenboim et al., 1999; Halevy et al., 1998; Wabeck and Skoglund, 1974). Lein et al. (2008) found that broilers have better gains and performance under dim light intensity. This is supported by previous research (Quentin et al. 2005, Blatchford, et al. 2009), which concluded broilers raised under dim light are less active, therefore often have better gains and sometimes improved feed: gain (F:G) ratios. Numerous studies have concluded that too much light is unhealthy for the broilers and can inhibit growth. This could be due to the fact that bright illumination encourages increased physical activity. Thus, one study stated that light intensities beyond 10.8 lx (lux) were

unnecessary and probably depress growth (Cherry and Barwick, 1962). This guideline has been quoted and used in research for nearly 50 years. Photoperiod is another important factor that has been thoroughly researched. Many studies have shown that intermittent lighting improved F:G when compared to continuous lighting (Andrews and Zimmerman, 1989; Buckland, 1975; Clegg and Sanford, 1951). Buckland (1975) also observed reduced mortality when broilers were reared under intermittent lighting.

Light Emitting Diodes (LEDs) are becoming increasingly more popular for use in poultry barns. Although more expensive initially, LED lights can last up to 50,000 hrs and are much more energy efficient compared to other kinds of lighting, especially traditional incandescent lighting. Although manufacturers have had quality problems with LEDs, they are now beginning to overcome some of the challenges they have faced by manufacturing reliable bulbs. Producers can now buy LED lamps in different wavelengths to put in their poultry houses and even power them with solar panels. As progress continues, knowledge will increase and more options will become available.

### **Spectral Sensitivity and Avian Vision**

Light is composed of a broad spectrum of electromagnetic waves (Figure 1-1). The visible portion of the EM spectrum is relatively small and is composed of wavelengths from roughly 350 to 800 nm. The eye of the chicken appears to be more sensitive to a broader spectrum than humans and chickens can see ultraviolet and infrared as well. Humans can usually see from about 400 nm to approximately 750 nm, and have a significant sensitivity peak at about 555 nm (green). Aves share this trait with humans, however, they also have other sensitivity peaks, one in red, and one in blue. This means that perceived light intensity, for birds, is considerably higher than it is for humans. In addition to aves' superior vision, they also have

advanced light receptors within the brain that play a great deal in biological and physiological functions. Although we do not yet fully understand the full function, it is thought that photostimulation helps to regulate normal behavior, and social interaction, as well as healthy circadian rhythms (Hartwig and Veen, 1979).

The function of ultraviolet vision in aves is something that is not fully understood but it is known that there are many different species of birds that share this phenomenon. Chickens, ducks, sparrows, starlings, and even hummingbirds have shown sensitivity to ultraviolet light outside the visible spectrum for humans. Scientists believe that some of the functions of having this heightened sense is to aid in orientation, foraging, signaling, or mating (Bennett and Cuthill, 1994). Research has shown that color vision comes from cone cells in the retina that interpret and send signals to the brain. Humans have three types of visual cone cells. Aves typically have five types of cone cells including a double cone which allows them to see in the ultraviolet spectrum. Many insects, fish, and even some rodents share these double cone cells. In the ultraviolet sensitive eye, these cones contain oil droplets in addition to pigments. The transparent oil droplets aid the fifth cone type, as mentioned above, and this allows light wavelengths to be absorbed outside the human visible spectrum (Bennett and Cuthill, 1994; Bowmaker & Knowles, 1976). Maddocks et al. (2001), conducted a trial to investigate the effect of the absence of ultraviolet wavelengths on broiler chicks. The researchers found basal corticosterone levels to be consistently and significantly higher in birds housed under UV deficient lighting. Corticosterone levels increase in response to stress so this indicates that the birds stress levels were higher without the UV light. Another study conducted by Zhang et al. (2006), explored the effects of ultraviolet radiation on skeletal development. Zhang found that UV light can improve skeletal tissue (bone weights) due to the fact that UV light stimulates and increased absorption of calcium

and phosphorus. It was also found that muscle growth was improved in chicks raised under UV light compared to those raised under UV free incandescent lighting. Edwards (2003) had previously discovered that exposure to UV light results in positive skeleton development. Edwards (2003) found, however, that when given in too large of quantity, UV light can be harmful to chicks. The benefits of UV light can be quite important in broiler production; however, most light sources in commercial broiler houses are lacking in UV light. Ultraviolet light has even been shown to increase fertility in broiler breeders, (Lewis and Gous, 2009), and has been used for sanitation purposes with broiler hatching eggs, (Coufal, et al. 2003). McCluskey, et al. (1967), looked at the effects of infrared lighting on broiler chicks. It demonstrated that infrared lighting stunted chick growth as well as feed conversion. However, it was surmised that this could have been due to temperature fluctuation within the house.

Trials have been conducted which examined the effect of low light levels on vision problems in poultry. Troilo, et al. (1995), looked at eye growth and the response to visual deprivation of light in layers. In egg production birds, it was found that when the eye is deprived of light, it grows larger and has a flatter cornea than when exposed to normal light. Jenkins et al. (1979), found the similar results in broilers. Chicks were divided into two groups, one group receiving light, and one group raised in total darkness. It was found that eye diameter and mean axial depth was greater in chicks raised in total darkness, supporting the fact that light deprivation can result in abnormal buphthalmic or enlarged avian eyes. Whitley et al. (1984), investigated photoinduced buphthalmic eyes under continuous bright light (1044 lux). The results were similar to Jenkins et al. 1979, where chicks were raised under darkness. Whitley et al. (1984), found that birds raised under continuous fluorescent light developed an enlargement of the eye as well. This supports earlier work done by Lauber and McGinnis (1966), who

compared layers raised under continuous light with birds reared on a 14L (hours light):10D (hours dark) photoperiod. Lauber, et al. (1961), also had found that continuous lighting in broilers can result in enlargement of the eye. In the previously mentioned study, McCluskey and Arscott (1967), it was found that chicks raised under infrared light had enlarged eyes compared to chicks raised under incandescent lighting. Although enlarged eyes may be of no harm to avian health or welfare, it is a condition that indicates something irregular in the environment for which the bird is compensating. When studying vision in broilers, it is important to remember the differences in spectral sensitivity between humans and avians.

## **Welfare**

It is becoming increasingly important to producers and consumers that poultry are raised in improved and comfortable conditions (Harper and Henson 2001). Consumers desire for animals to be well fed, well housed, live a pain free normal life, and a humane slaughter. Consumers equate good animal welfare standards with healthy food. New laws and regulations have been implemented in the United States and Europe in efforts to improve poultry welfare. With concerns about animal welfare and well-being, it is important to implement lighting programs that allow birds to live a normal life. Implementing a light schedule or photoperiod, allows birds to rest a few hours each day, similar to natural settings. Photoperiods can help ensure normal behavior patterns and healthy circadian rhythms (Bessei, 2006). Light management can play a part in reducing cannibalism in poultry (Olanrewaju et al. 2006). This work demonstrated that decreasing light intensity or using different wavelengths of light can decrease incidents of cannibalism. Some research has been conducted that suggests avians raised under very dim light can suffer from eye problems. Ashton, et al. (1973) stated that low light levels (0.2 lux) may cause damage to the eye or blindness may occur. Blatchford et al. (2009),

concluded broilers reared under 5 lux have greater eye weights than those raised under brighter light. Increased eye weight can be caused by possible inflammation or degeneration, which supports the theory that low light levels are harmful to the welfare of broilers and inhumane.

Although consumers and producers are concerned with animal welfare, producers must also consider economics. Some studies show that dim light is detrimental to welfare, but much research indicates broilers have better performance under less intense light (Cherry and Barwick 1962; Quentin et al. 2005; Lein et al. 2008, Blatchford et al. 2009). Producers usually take advantage of additional gains and reduced energy costs from using less intense lights. There are two sides to an important issue, and it is an ever growing debate. From an economical standpoint, management strategies should focus on what is optimal for broiler welfare and growth performance at the same time.

### **Bird Light Preference**

Little research has been done on bird light preference. A few studies have explored light color and intensity preferences of broiler chicks as well as preferences of hens for different light sources and intensities. Berryman et al. (1971), investigated complexity and color preferences in chicks at different ages. Although not a light study, this experiment explored chicks' responses to the colors and patterns of the floors of their pens. The researchers found that chicks prefer the color red compared to gray or complex pattern designs in the pen floor. When the color red is not present, they prefer complex patterns especially as they grow older. Taylor et al. (1969), also tested chicks' preferences in a similar way. One day old chicks' preferences were investigated and compared using different colors. A rectangular box was designed, and different colors were placed at each end. The closer the chick moved to one side, indicated the bird preferred one color over another. In experiment 1, red and blue were

compared. The chicks showed a clear preference for red. When yellow and blue were compared, chicks preferred yellow. The study also indicated that when chicks were trained (raised) under a particular color of light, they preferred that color of light during the test. The control chicks which were raised under white light, didn't show a preference for red or blue from four to seven days old. The study also showed that the longer chicks were exposed to certain stimulus (light color) the more likely they would prefer that particular color when given a choice. Davis et al. (1999), conducted a light intensity preference study on chicks at 2 and 6 weeks old. Chicks were allowed to choose different chambers with varying light intensities: 6, 20, 60, and 200 lux. The chicks, at 2 weeks of age, preferred the brighter light, but when the birds grew older (6 weeks), they spent more of their time under the dim light. It is important to know that broilers did prefer brighter light at both ages for activities like eating, drinking, and floor-pecking. Alvino et al. (2009), conducted a study on broiler behavior under different light intensities: 5, 50, or 200 lux during the photophase and 1 lux during the scotophase. The photophase is the period when lights are on and birds are usually awake, while the scotophase is the period when lights are off and birds are often resting. The photoperiod was set at 20L:4D. The researchers found that the birds raised under 5 lux had a more even dispersal of activity than those raised under brighter intensities. This means the broilers raised under 5 lux spent more time involved in inactive behaviors (such as sleeping) while the rest of them were active and they didn't show a normal behavioral rhythm of active and inactive behaviors each day. The work indicates the broilers raised under the 50 or 200 lux, had normal behavioral rhythms, meaning they did more resting during the scotophase than did the broilers raised under 5 lux, which often were active during the scotophase. Kristensen et al. (2002), conducted a light quality preference study on broilers. The broilers were allowed to choose which type of light source they preferred. Their options were



Biolux tubes (similar to daylight), warm white fluorescents, incandescent light, and a special light environment which matched the spectral sensitivity of the fowl which was built using varieties of fluorescent tubes and gel filters. This lighting had wavelengths that peaked in the exact places that avian sensitivity peaked. It was reported that broilers preferred the biolux lighting (daylight) over incandescent and spectral sensitivity matched light but did not prefer biolux over the warm white fluorescent lighting. Heshmatollah (2007), conducted a light study on broiler lighting preference and preference for colored feed. It was found that broilers had no preference when given different light intensities (1.5, 9, 65 lux), but when given the option of red, orange, yellow, or green light, they spent significantly more time under green light. Their second preference was yellow. Additionally, broiler food color preference was tested with feed dyed red, orange, yellow, or green with food coloring. It was observed that chicks under 1.5 lux consumed more orange feed ( $P < 0.05$ ) but under the brighter intensities they consumed more green feed.

Widowski et al. (1992), examined laying hens' preferences for compact fluorescent over incandescent lighting. A poultry house was divided in half and incandescent lighting was installed in one section and fluorescent lighting in the other section. The hens were then allowed to walk from section to section and choose which light source they were under. It was found that hens spent more time under the fluorescent lighting than incandescent, spending approximately 75% of their time under the fluorescent lighting. A similar study, Vandenberg and Widowski (2000), studied hen's preference for high-intensity high-pressure sodium or low-intensity incandescent lighting. They found no statistical differences in hen's light preference between these two light sources. They spent an equal amount of time under each type of lighting. However, when individual behaviors were investigated under each light source, it was found that

birds spent more time nesting, preening, ground-pecking, and drinking under high-pressure sodium fixtures. 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 et al. (1999).

## **Light and Behavior**

Behavior can be affected by intensity of light as well as wavelength. In most studies it is found that a brighter intensity increases bird activity (Newberry et al. 1988). Blatchford, et al. (2009), conducted a study examining behavior of broilers raised under 5 lux, 50 lux, and 200 lux. It was concluded that broilers are less active under 5 lux conditions when compared to the other lighting treatments. Newberry, et al. (1988), compared very dim light to very bright light (6 lux to 180 lux) and discovered similar results. Many studies have found that birds raised under dim light have better F:G ratios simply due to less loss of calories from physical activity. Prayito et al. (1997), conducted a study comparing broiler behavior under red, white, blue, or green lighting. It was concluded that broilers raised under red and white light were more active than those raised under blue and green light. It is important to understand the effect of light on the behavior of broilers as it can directly lead to changes in bird performance.

## **Wavelength**

Numerous studies have been conducted on effects of wavelength (or color) on broiler performance (Kondra 1961). Researchers typically have compared white light with blue, green, and red light. Generally it is believed that green or blue light results in better performance, possibly due to a calming effect on broilers (Prayito et al. 1997 a). Some research has demonstrated that broilers raised under blue or green light become heavier while feed conversion

and mortality remain unaffected (Lauber and McGinnis, 1961; Wabeck and Skoglund, 1974; and Rozenboim et al, 1999). Rozenboim et al. (1999), conducted a study which broilers were grown under different colors of light; blue, green, red, and white. It was found that blue and green both stimulate growth but that the onset of the enhancement occurred at different times. It was concluded that green light stimulates early growth while blue light stimulates growth in older broilers. Rozenboim, et al. (2004), conducted a study to investigate the effect of changing light color (green and blue monochromatic light) at different ages on the growth performance of broilers. Chicks were raised under blue, green, or white light (control) and were switched from blue to green light and from green to blue light at 10 days of age and again at 20 days of age. The results indicate that switching birds from green to blue light at 10 days of age, accelerates growth of broiler chickens. Halevy et al. (1998), investigated skeletal muscle growth and satellite cell proliferation in broilers. Chicks were raised under monochromatic lighting and the treatments were: green (560 nm), blue (480 nm), and red (660 nm), with white light serving as the control. Broilers raised under blue or green light had greater satellite cell count than those raised under red or white light indicating that blue or green light stimulates growth in broilers. Cao et al. (2008), used LED lights, and conducted a trial again comparing the effect of raising broilers under red, white, blue, and green lighting. They concluded that green light promotes early growth, and blue light promotes later growth. By the end of the trial, broilers raised under blue light had higher BWG. Kondra, (1961), found no statistical differences in BWG or F:G when comparing red, green, and white light in both broilers and young poults. Wathes et al. (1982), also compared blue, green, red, and white lighting, at varying intensities on broilers. No differences were observed in body weight or feed consumption.

Red light has been shown to decrease the growth and sometimes reduce feed conversion of broiler chickens (Wabeck and Skoglund, 1974), but has also been shown to help production with laying hens or breeders as red light is thought to stimulate reproductive performance. Foss et al. (1972), researched the development of cockerels raising birds under blue, green, red, and infrared light, and in complete darkness. No differences were found in feed consumption, but roosters raised under green light had higher BWG. Testes and comb weights were taken, and it was shown that both were larger under the red light supporting the idea that red light stimulates reproduction. Rozenboim et al. (1998), conducted a study to test effects of different light wavelengths on layer performance. Layers were housed under wavelengths of 560 nm (green), 660 nm (red), and 880 nm (infrared). Egg production at 58 weeks was statistically poorer ( $P < 0.05$ ) under the infrared lighting, and they concluded that this was due to the chickens' inability to see at this wavelength of infrared. Er et al. (2007), found that when young layers were exposed to red LED lights they produced smaller eggs than when housed under blue, green, or white lighting. In the same trial, layers that were housed under green lighting had higher eggshell quality compared to those housed under blue or white lighting. Adequate egg shell quality is important for egg collection, cleaning, packaging, and transportation to minimizing losses.

Xie et al. (2008), conducted a study using LED lights of different color to explore the impacts on the immune response of broilers. They were raised under blue, green, red, and white lamps. It was found that broilers reared under white light had the highest peripheral blood T-lymphocyte proliferation response compared to blue, green, or red light. This is important for healthy immune function. However it was found that blue and green light helped promote greater antibody production and immune function, compared to red light. The researchers also

concluded that blue light alleviates negative effects of stress on broilers, leading to a well-balanced immune response, especially in older broilers. Prayito et al, (1997 a), conducted a study comparing red, green, blue, or white light at 30 lux intensity. Broilers were reared for one week under one of the colors. Then, they were placed in a pen where different light colors were placed in sections, and chicks could choose which light color they preferred. After becoming adjusted to surroundings, most chicks chose blue and a few chose green light. Broilers under red or white light were more active than those raised under blue or green. This study helps to support the theory that green or blue light creates a calming effect on birds that starts with photostimulation and in the end can help bird performance. Prayito et al. (1997 b), went on to compare BWG considering just the effects of red and blue light. Chicks raised under blue light were less active than those raised under red light, and had higher BWG than birds raised under the red lighting.

### **Intensity**

Light intensity is another important factor to consider in raising broilers. Light levels can be measured in different ways. In many earlier studies, light intensity was measured in foot candles. Light intensity can also be measured in watts/ sq. meter. Lux level is the measurement that is most common in current research (1 foot candle is = to approx. 10 lux). In the commercial industry, light levels have been lowered to reduce energy costs. Additionally, some studies have shown that low light intensities can often improve broiler performance (Lein et al. 2008). Low light levels usually decrease physical activity resulting in more resting and sleeping, and therefore faster BWG. Also low light intensities are thought to help reduce cannibalism because the low intensity decreases activity and ability to see clearly while picking. Therefore, the birds lose interest in establishing a pecking order. Although some studies indicate an improvement in

BWG and performance, there are others that show no effect (Skoglund and Palmer, 1962; Deaton et al. 1976; and Kristensen et al, 2006). Blatchford et al. (2009), conducted a study examining behavior, eye, leg, and immune health of broilers raised under 5 lux, 50 lux, and 200 lux. It was concluded that broilers are less active under five lux when compared to the other two treatments. There were no differences found in BWG or F:G. Newberry et al. (1986), compared 0.1, 0.5, 1, 10, 20, 30 and 100 lux intensities in 2 different experiments. These trials had also found no differences in BWG, however they indicated an increase in feed consumption as light intensity increased. Newberry et al. (1988), compared 180 lux vs 6 lux, and found that broiler activity was significantly decreased under the dim lighting but feed consumption, BWG, and F:G, were unaffected by light intensity. Quentin et al. (2005), discovered that high light intensity significantly reduced feed intake and growth rate by 3.2%. It was reported that this was not thought to be from the level of physical activity. Deaton et al. (1988), considered the effect of light intensity on abdominal fat deposition in broilers and concluded that light intensity did not have an effect. Deaton, et al. (1989), also found no differences in BWG or F:G ratio when comparing light intensities. Prayitno, et al. (1997 B), also concluded that light intensity did not have an effect on BWG in broilers. Kristensen et al. (2006), conducted a study exploring the impact of light intensity on leg health and broiler performance. Broilers were either reared under 5 or 100 lux, but again no differences were found in BWG or in leg health. Perhaps some the differences in results among studies could be due to trial methods or design, type of lighting, time of year, or other treatment factors.

Cherry and Barwick, (1962), had stated that light intensities beyond 10.8 lux were unnecessary and could depress growth, yet researchers continued to study high light intensities and their effects on broiler behavior and performance. Since this earlier work, animal welfare

issues have increased to ensure that birds are raised under comfortable lighting conditions. Some research has been conducted that suggests avians raised under very dim light suffer from eye problems. Ashton, et al. (1973) stated that when low light levels (0.2 lux) are used it may cause damage to the eye or blindness may occur. Blatchford et al. (2009), concluded that broilers reared under 5 lux had greater eye weights than those raised under brighter light, suggesting possible inflammation or degeneration, which may support the theory that low light levels are inhumane and harmful to the welfare of avians. However, it could have been the birds' effort to compensate for low light conditions.

Several studies have also been conducted that indicate a positive correlation between low light levels and better broiler performance (Skoglund and Palmer, 1962; Deaton et al. 1976; and Lien et al. 2008). Deaton et al. (1976), compared continuous lighting at a low intensity (12.9 lux), with a 12L:12D photoschedule and a bright light intensity (204.5 lux). It was found that broilers had greater BWG under the continuous dim lighting, however, this could have been due to photoperiod rather than light intensity. Jenkins et al. (1979), compared broilers raised under 12 hrs light/day to broilers raised in complete darkness. It was interesting that BWG showed no differences. However, the behavior and social interactions of chicks raised in darkness were not normal compared to chicks raised in light. Skoglund and Palmer conducted numerous trials comparing bright lighting (120 foot candles) to less intense lighting (all the way down to 0.5 foot candle). It was concluded that raising broilers under light levels as low as 0.5 foot candle could be possible for maximum broiler gains. McKee et al. (2009), studied the effect of light on breast meat characteristics. It was reported that broilers raised under low light intensity (1 lux) had greater overall body weights and greater breast meat yields. Marosicevic et al. (1990), conducted a trial comparing different light wavelengths and intensities. It was found that the

greatest BWG and F:G came from broilers reared under low intensity of blue lighting. This could have been from the effect of wavelength rather than from intensity. It was also concluded that light intensity had little or no effect on broiler health in this experiment. Lien et al. (2008), noticed improved BW under dim light (1 lux) vs (150 lux) however F:G was not affected. Yahav et al. (2000), reported that F:G in turkeys improved under low light. Kjaer and Vestergaard (1999), investigated feather pecking in relation to light intensity. Feather pecking was classified into 3 categories; gentle peck, medium peck, and severe peck. They compared 3 lux to 30 lux and found that it was more likely for broilers to peck gently when raised under dim light. The broilers raised under 30 lux were more likely to peck severely at each other. This study shows how dim lighting can reduce feather pecking and therefore increase bird welfare.

Renema, et al. (2001), studied the effect of light intensity on egg production. Four strains of commercial layers were housed under 1, 5, 50, or 500 lux. Egg production improved from 1 to 50 lux, but declined at the 500 lux treatment. Growth performance was lower under 1 lux compared to the other 3 treatments.

From past research, it could be concluded that light intensity can have an effect broiler performance, but in many cases F:G and BWG are not affected by light level directly. Wavelength and photoperiod are other treatments that are included and it is likely that observed differences are from these other factors as well, rather than just from light intensity. There have been few cases where dim light has negatively affected broiler performance compared to brighter intensities. Knowing this, from an economical standpoint, producers would tend to implement a lighting program saving electricity and using dim lighting in broiler houses where possible (5-10 lux).



## **Photoperiod (Intermittent Lighting)**

The effect of intermittent lighting on poultry has proved to be a management tool that can be used to improve growth performance, poultry health, and economics. Beane et al. (1962), conducted an experiment comparing 2 photoperiods: 8L:16D vs a 1L:2D cycle. A control group received continuous lighting throughout the experiment. It was found that the control group under continuous lighting performed better than intermittent lighting programs, with the 8L:16D showing the poorest performance. Deaton, et al. (1978), conducted 2 experiments comparing continuous and intermittent lighting. In the first trial, one treatment consisted of continuous light, and the other consisted of 15 minutes of light followed by 105 minutes of darkness. In the second experiment, one treatment had 12 hr of bright light (237 lux) followed by 12 hr of dim light (7.5 lux), and the other had continuous light at 75 lux for the first week followed by 15 minutes of light at 7.5 lux followed by 105 minutes in darkness. Deaton et al. (1978), observed that F:G ratios were significantly improved under 15(minutes)L:105(minutes)D, compared to the other treatments and continuous lighting. Brickett et al. (2007), compared 12 (hours)L:12 (hours)D to 20L:4D photoperiod, and concluded that the 12L:12D reduced broiler gains and performance. Rahimi and Rezaei, (2005), conducted a study on intermittent lighting. They compared a 1L:3D versus 23L:1D photoperiod schedule. Chicks under CL (Continuous Lighting) were observed to be heavier than those under the IL (Intermittent Lighting) in the first 10 days. This suggests for maximum weight gain to use CL when birds are < 10 days of age. The researchers discovered that feed conversion ratio was improved when birds were grown using intermittent lighting. Lein et al. (2008), researched dim lighting and increased photoperiod and observed significantly higher BWG and feed consumption under these conditions. However,

F:G was not affected in this experiment, potentially due to increased feed consumption that led to increased body weight.

Cherry and Barwick (1962), conducted a series of experiments with different photoperiods. In the first experiment, photoperiods were set to: 23L: 1D, 2L: 2D, 1L: 2D, and 1L: 1D. No differences were found in BWG, feed consumption, or F:G ratios. Cherry and Barwick (1962), conducted another experiment where photoperiods were 1L: 2D, 1L: 3D, 1L: 5D, and 1L: 7D. At 8 weeks of age, broilers raised under the longer periods of darkness were heavier than those raised under shorter periods. The researchers expanded upon these results by conducting another trial where photoperiods were 23L: 1D, and total darkness after seven days. The broilers raised under total darkness were lighter than those raised in light up until 6 weeks of age. After 6 weeks of age there were no differences between treatments in BWG, or F:G ratios. It was concluded that it might be optimal in a commercial operation, to have no longer than 2 hrs dark per cycle to maximize BWG. Stanley et al. (1997), conducted an experiment utilizing natural light through part of the growing phase and finishing stage. The broilers were grown to 7 weeks of age. One house was given continuous light throughout the entire experiment. The rest were transferred from the natural lighting program to the continuous lighting program at different stages of their life; 2 W (Weeks), 3 W, 4 W, and 5 W. It was found that broilers transferred at 5 weeks of age from natural lighting to continuous lighting, had the greatest BWG. Also, F:G was greater in this group as compared to the control group. Perhaps a natural light program, utilizing outside light through the curtains, is an economical method to help achieve satisfactory performance.

Broilers are known for their ability to gain extreme amounts of weight in short periods of time. Unfortunately this can lead to health problems due to growing faster than their

cardiovascular, or skeletal system can support. This can cause sudden death, crippled birds, and overall, loss in production value. If one can reduce early growth rate, allowing the broilers' skeletal and circulatory systems a chance to develop ahead of skeletal muscle, it can reduce health concerns. One way to do this is intermittent lighting programs. Although there are some conflicting results, it is generally thought that intermittent lighting strategies can help achieve high BWG, favorable F:G ratios, and when used right, can help reduce health problems. Calvet, et al. (2009), conducted a research trial and discovered that dust production in a broiler barn is 4 times greater feeding time (Light) than during the resting time (Dark). Intermittent lighting can help control dust, and this can reduce respiratory sickness and other health problems.

### **Effect of Light on Incubation and Post Hatch Growth**

Research has been conducted exploring the effect of light on embryos, incubation, and post hatch growth. Early research also tested the effect of cold stressing birds during incubation (Buckland, 1970). It has been shown that this practice can result in a higher hatching weight in broilers. Buckland (1970), tested exposing embryos to cold stress for a period of 0, 2, 4, 6, 8, 10, or 12 hours at 5 to 7 degrees Celsius. After hatching, chicks were placed on two lighting programs: intermittent light and continuous light. It was found that hatching weight was increased when exposed to cold stress as embryos, but at market weight broilers were lighter in body weight and mortality was extremely high when birds were cold stressed for longer than 8 hours regardless of lighting. Intermittent lighting, however, did help to reduce mortality compared to continuous lighting and also resulted in higher body weight. Archer et al. (2009), studied the effect of providing light during incubation for broilers. Continuous lighting (24L:0D), 12 hours (12L:12D), and no lighting (0L:24D) were compared. No differences were found in hatchability, mortality, BW, or F:G ratio, but it was found that eggs incubated under light were

less stressed than those incubated without light. Cooper (1972), studied the effect of light during incubation on hatchability in turkeys. In two separate incubators, lighting treatments were compared. In one, the eggs were kept under fluorescent lighting and the other was left in complete darkness. Though the differences were not significant, it was found that percentage hatch was greater when eggs were held under lighting during incubation.

Rozenboim, et al. (2003), also conducted two studies on embryonic photostimulation in turkeys and effects on posthatch growth. In the first study, one group of eggs were held under intermittent green LED lighting. The control group was left in darkness. Female poults, at market age were statistically heavier when incubated under light. However, the males showed no effect. In the 2<sup>nd</sup> study, there were three groups of eggs. The first group was again kept under green lighting, the second group was incubated under white incandescent lighting, and the third was kept in darkness. It was found that poults incubated under white incandescent lamps hatched sooner than the poults incubated under the other treatments. Eggs incubated under green light had a slightly higher hatchability as well. It was concluded that green LED light improves hatchability and stimulates growth in turkeys. Rozenboim et al. (2004), conducted a similar trial on broiler chickens. Again green LED lights were used in the incubators compared to the control group which were left in the dark. Similarly, it was found that chicks incubated with green light had higher BWG one week post hatch than those that were not. By 42 days of age, broilers were still heavier when exposed to green light in the incubator ( $P < 0.05$ ).

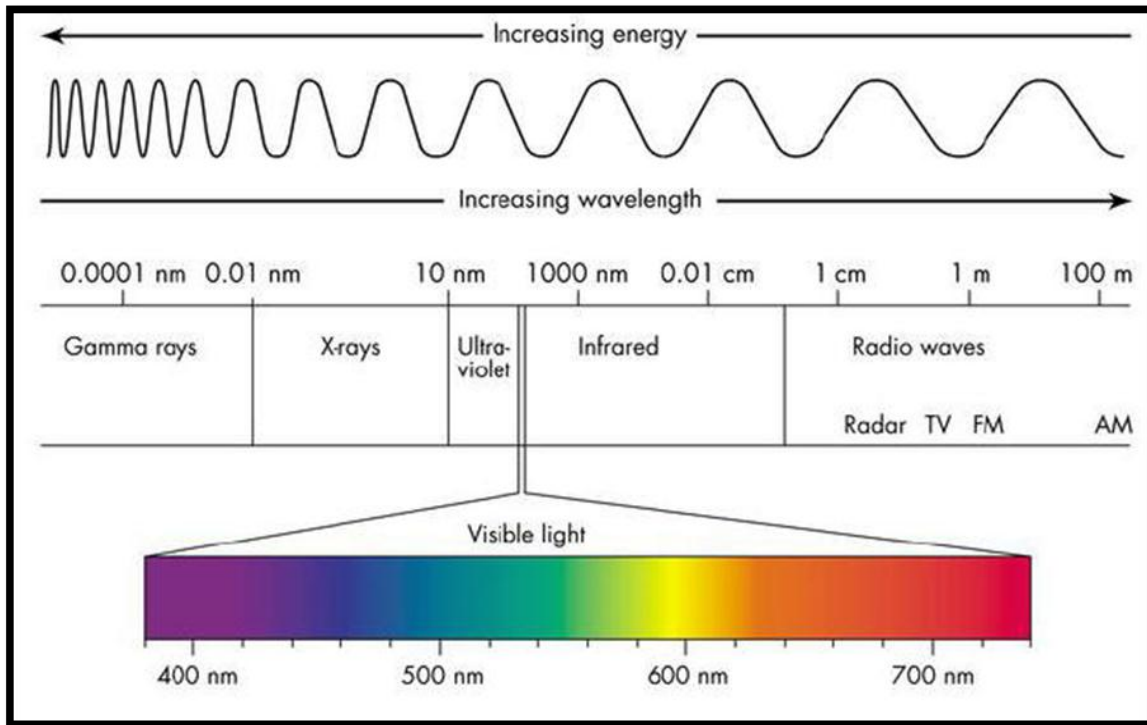
It is important that hatcheries take into account the effect that lighting can have on the health and hatchability of their chicks. Light stimulation should be implemented with incubators in hatcheries for the benefit of the companies as well as the chicks' overall health and better performance later at the grow out facilities.

## **LED and other Light Sources**

Poultry producers of today have many options for the different sources of lighting they can implement in their poultry facilities. The traditional incandescent bulb is inefficient compared to other alternatives that are now available. New regulations will require producers to stop using the incandescent bulb because of its inefficiency. Some of the new light sources available are low pressure mercury, or fluorescent lighting (available in standard tubes, or compact bulbs), mercury vapor, metal halide, high-pressure sodium vapor, low pressure sodium vapor, and light emitting diodes (LEDs). Although these new light sources are usually more efficient and often improve the quality of lighting in our poultry houses, research on the effect of these different kind of lights on broilers is lacking. These light sources can vary greatly in their capacity to properly light a building, as well as their wavelength. An incandescent bulb has a wavelength from about 350 to over 2800 nm. With incandescent lighting, around 90% of the energy required is wasted as heat. A fluorescent tube has a wavelength from about 350 to just over 800 nm, and much energy less is wasted. However, there is concern, that with the fowl's superior eyesight that they can detect the flicker of fluorescent lighting, that is invisible to humans. Scheideler (1990), conducted a large commercial size study comparing fluorescents to incandescent lighting. It was found that light source had no effect of BWG, feed conversion, or mortality on broilers. Fluorescent lights proved to be much more energy efficient than incandescent. LEDs have a wavelength ranging from the UV into the infrared spectrum. Very little energy is lost as heat compared to the incandescent lighting as well. Rozenboim et al. (1998, 1999, 2004), also conducted research with LED lighting in layers and broilers. The researchers experimented with different light colors and intensities. Positive effects and no detrimental effects upon broiler performance were found when using LED light. Although

more research is needed to better understand how broilers view different kinds of light sources, there is no evidence that any new light sources have serious negative performance on broilers (Lewis and Morris, 1998).

**Figure 1-1 Electromagnetic Spectrum**



[www.antonine-education.co.uk/physics\\_gcse/Unit\\_1/Topic\\_5/topic\\_5\\_what\\_are\\_the\\_uses\\_and\\_ha.htm](http://www.antonine-education.co.uk/physics_gcse/Unit_1/Topic_5/topic_5_what_are_the_uses_and_ha.htm)

## Chapter 2 - The Effect of LED Light Intensity on the Growth Performance of Commercial Broiler Chicks

### Abstract

As energy costs rise, producers must consider all new technology as part of their farm management strategy. Light emitting diode (LED) sources are relatively new and potentially beneficial to poultry producers due to lower energy cost. In order to test the efficacy of LEDs as a light source for growing broilers, the following experiments were conducted, utilizing 5 different light intensities as treatments. The LED light intensities varied from 5 to 25 lux, in increments of 5 lux. Four hundred newly hatched male Cobb 500 broiler chicks were placed in pens with 20 birds/pen and 4 pens/treatment. The experiments were carried out in a single building using 1.52 x 3.66 meter diameter pens. Experiment 1 was conducted in the late summer/early fall and experiment 2 was conducted in the late winter/early spring. The chicks were fed a standard NRC corn soy starter diet and were grown to 21 days of age. White LED light strings were bunched into clusters with 50 small bulbs per cluster and hung 24 inches above the floor litter, and served as the light source for the experiments. Chicks were raised for the first 3 days using incandescent ceiling bulbs, and on day 4 experimental treatments started. The LED lights were on a 24L:0D light schedule. All pens were given *ad libitum* access to feed and water. BWG and feed consumption were collected at 21 days. Data was collected and analyzed in SAS using linear, quadratic, and cubic comparisons to test for significance ( $P < 0.05$ ). A significant linear relationship ( $P < 0.05$ ) was found in experiment 1 between BWG and light intensity. In experiment 2, body weight gain showed a linear trend meaning, as the light intensity increased, the chick weight increased. A significant linear relationship ( $P < 0.05$ ) was also found in both experiments 1 and 2 between feed consumption and light intensity. As intensity increased, so did



feed consumption. Feed: gain ratios were not affected by light intensity. The data concluded that more intense LED lights could lead to improved body weight gains.

## **Introduction**

Many new lighting technologies are currently being developed as energy sources increase in cost and producers are looking for ways to save money. Among new lighting technologies emerging on the market are light emitting diodes (LEDs). Although initial capital costs are higher for the producer, LED lights use electricity more efficiently compared to traditional lighting and will pay for the investment over time. LED lights usually have a life of over 50,000 hrs requiring less frequent replacement thus reducing maintenance costs. Early light research has been conducted on light intensity and its effect on broilers. These studies served as the starting point for LED light research. Cherry and Barwick (1962), stated that light intensities beyond 10.8 lux were unnecessary and could depress growth. Kristensen, et al. (2006), conducted a light study looking at leg health and broiler performance under different light intensities. Chicks were either raised under 5 or 100 lux, but no statistical differences were found in BWG or in leg health. In another study, Blatchford, et al. (2009), conducted a study examining behavior, eye, leg, and immune health of broilers raised under 5 lux, 50 lux, and 200 lux. It was found that birds were less active under the 5 lux intensity. Birds raised under 200 lux were found to have more hock and footpad bruising, suggesting increased physical activity. No differences were found in body weight gain, however, broilers exposed to 5 lux had increased eye weight compared to those raised under the other 2 intensities. Rozenboim et al. (1998, 1999, 2004) has conducted research with LED lighting in layers and broilers. The researchers experimented with different colors and intensities. Positive effects on performance were found from using LED lights.

There have been prior research contradictions and there is an inability to apply some of the research to field situations due to infeasibility in the industry. For example, light intensity may be too bright for facilities or facilities would not be equipped for lighting management programs tested. Two experiments were conducted to investigate the effect of LED light intensity on body weight gain and performance of broiler chicks, using light intensities that are realistic, and attainable in commercially simulated production facilities.

## **Materials and Methods**

All broilers were raised following protocols established by Kansas State University Institution of Animal Care and Use. Experiments were conducted at the Thomas B Avery Poultry research unit. Experiment 1 was conducted in the late summer/early fall and experiment 2 was conducted in the late winter/early spring. Four hundred newly hatched Cobb 500 male broiler chicks were grown to 21 d of age in floor pens with used pine shaving litter. Twenty birds were placed in each of the 1.52 x 3.66 meter pens and 5 light intensities were compared. A ziggy nipple water drinking system was set up in each pen and was manually adjusted as birds grew to ensure the watering system was kept at a proper level. Self-feeding feeders (Choretime C3 bottom dispensers) were placed in each pen. The feeders were checked twice daily and feed was weighed and manually added when needed. LED lights strings were bunched into clusters and hung 24 inches over floor litter. Each string contained 50 small bulbs and they were pointed in a downward direction lighting the pens. The light intensities were set from 5 to 25 lux, in increments of 5 lux using dimmer switches. A light meter<sup>(1)</sup> was placed directly under the lights at the brightest point and the light intensity measurement was taken. The light dimmers were installed in each pen to allow ease of adjusting lux intensities, and the lights were tested every

1) model # FSC-06-662-64 Fisher Scientific.

other day with lux detector to assure that intensities were kept at desired levels. Most lights did not fluctuate in intensity, while some changed a small amount, approx. 1-2 lux between adjustments. Black plastic was suspended in between each pen to prevent lighting from interfering with neighboring pens. The chicks were raised for the first 3 days using incandescent house lighting, to allow them to adjust to surroundings. On day 4, the LED lights were adjusted to treatment intensities and the incandescent lights were turned off. The LED lights were left on a 24 hr light schedule. During daylight hours the house curtains were dropped when necessary to prevent over heating. During the summer trial this happened every day as a result of the hot temperatures and in the later trial this did not occur as often. Only on a few days when temperatures increased and the broilers needed to cool down the curtains were dropped. The chicks were fed a standard NRC (1994) corn soy starter diet, and all pens were given *ad libitum* access to feed and water. Body weight and feed consumption was collected at 21 days.

### **Statistical Analysis**

Data was collected and proc mixed, lsmeans, proc univariate normal plot producers were run using SAS.<sup>(1)</sup> Also linear, quadratic, and cubic comparisons were analyzed to test for significance ( $P < 0.05$ ).

### **Results Experiment 1& 2**

Table 2.1 shows the results of BWG, pen consumption, and F:G ratios. The results indicate that BWG and feed consumption increased linearly with light intensity ( $P > 0.05$ ) indicating that brighter light intensity increased weight gain. Feed to gain ratios were not statistically effected by light intensity.

(1) Version 9.0 provided by SAS Institute Inc. Cary, NC.

Results for experiment 2 were similar to those observed in experiment 1. Table 2.2 shows the results of BWG, feed consumption, and F:G ratios. Feed consumption was significant in a linear fashion in relationship to light intensity ( $P > 0.05$ ), but body weight gain only showed a linear trend in experiment 2, only approaching significance ( $P=0.066$ ). As observed in experiment 1, the F:G ratios remained unaffected by light intensity.

## **Discussion**

Past research has shown that dim lighting is thought to increase BWG and improve performance. (Skoglund and Palmer, 1962; Deaton et al. 1976; and Lien et al. 2008) conducted studies and indicated positive correlation between low light levels and better broiler performance. Although some data shows light intensity having a difference upon performance factors (BWG, and F:G ratios), other data shows no statistical differences resulting from light intensity (Blatchford, et al. 2009). This may have been due to differences in the individual trials, time of year, or the performance was affected by factors other than light intensity. Wavelength and photoperiod are often included in data analysis and it is possible that when statistical differences are found from an experiment, these other factors contribute as well. Deaton et al. (1976), compared continuous lighting at a low intensity (12 lux), with a 12L:12D photoschedule and a bright light intensity of 205 lux. It was found birds had better BWG under the continuous dim lighting, however, this could have been due to photoperiod rather than light intensity.

In this trial it was observed that the body weight gains for Experiment 1 were not as high as the weight gains for Experiment 2. A possibility could have been that experiment 1 was conducted in the late summer/early fall and despite the fact that house curtains were dropped daily, the chicks experienced more heat stress when compared to those grown later during cooler winter temperatures. The F:G ratios also improved during the cooler time supporting this

observation. Heat could have also affected movement and social activities which affected performance data between trials.

In both experiments, the statistical linear relationship demonstrated that under brighter intensities, BWG increased. It was observed that along with the higher weight gain in these experiments came increased feed consumption under the brighter light. In these conditions, with the available light source, broilers may have better performance with brighter light intensities. In this trial it could have been that chicks could locate feed and water more easily under the brighter light and thus it increased feed consumption and therefore BWG. From the results of this trial, it could be suggested to producers that under LED lights, it may be worth the extra cost of using brighter intensities.

**Table 2.1 The Effect of LED Light Intensity on Performance of Commercial Male Broiler Chicks (Experiment 1).**

Light Intensity (Lux)	BWG (g)	Pen Feed Consumption (kg)	F:G Ratio (kg feed: kg gain)
5	1335.43	39.848	1.615
10	1349.13	42.102	1.621
15	1346.45	40.842	1.619
20	1399.37	41.256	1.594
25	1413.15	45.277	1.622
SEM	30.273	14.023	0.026
P Values for Conducted Tests			
Linear	0.048*	0.039*	0.864
Quadratic	0.629	0.337	0.821
Cubic	0.815	0.129	0.485

Above means analyzed using linear, quadratic, and cubic comparisons to test for significance.

\*Test Values <.05 differ significantly.

**Table 2.2 The Effect of LED Light Intensity of Performance of Commercial Male Broiler Chicks (Experiment 2).**

Light Intensity (Lux)	BWG (g)	Pen Feed Consumption (kg)	F:G Ratio (kg feed: kg gain)
5	1471.9	43.589	1.481
10	1480.08	43.352	1.503
15	1480.71	44.254	1.493
20	1535.87	46.297	1.495
25	1540.61	46.305	1.503
SEM	30.78	10.597	0.021
P Values for Conducted Tests			
Linear	0.066	0.025*	0.593
Quadratic	0.685	0.688	0.827
Cubic	0.666	0.371	0.566

Above means analyzed using linear, quadratic, and cubic comparisons to test for significance.

\*Test Values <.05 differ significantly.

## **Chapter 3 - Effect of LED Lights on Growth Performance and Behavior of Broiler Chicks.**

### **Abstract**

Light intensity and feed form has been proven to have an effect on broiler behavior and growth. The following trial was designed to investigate the effects of LED light intensity combined with feed form on broiler behavior and performance. Twelve hundred eighty Cobb 500 broiler chicks were randomly chosen and placed in pens with 40 birds/pen and 4 pens/treatment. Pens were 1.52 meters wide and 3.66 meters long. The chicks were grown under white LED lighting at 4 different light intensities: 10, 20, 30, and 40 lux. The light lamps hung 48 in. above the litter, making a ring of light over the feed and water. Black plastic was suspended between each pen to prevent stray light interfering with neighboring pens. Feed and water were provided *ad libitum*. From 0-3 weeks chicks were all given crumbled feed and then from 3-6 weeks half remained on crumbles and the other half were fed pelleted feed. Broiler behavior was observed and recorded each week under the different light intensities. Activities monitored included time spent lying, standing, eating, and drinking. Broilers were weighed at 3 and 6 weeks of age (by pen average at 3 weeks and individually at 6 weeks).

It was found that feed form improved feed conversion ratios for pelleted vs crumbled feed in both 3-6 weeks and 0-6 weeks ( $P < 0.05$ ). Also, the percent of time the birds spent eating during the starter phase was greater under 40 lux than in the other 3 treatments ( $P = 0.0447$ ). A high amount of variation was found in BWG in this trial. Four tests were conducted to determine normality in terms of variability: Shapiro-Wilk, Kolmogorov-Smirnov, Cramer-von Mises, Anderson-Darling ( $P < .05$ ). It was found that many pens had a high degree of abnormal



variation. The effects of light intensity in this trial were not found to be significant on BWG, Pen consumption, or F:G ratios.

## **Introduction**

Numerous light intensity studies have been conducted before on broilers. The effect of light on gains, broiler health and behavior has been considered. Cherry and Barwick, (1962), stated that light intensities beyond 10.8 lux were unnecessary for raising broilers and could depress growth. Subsequent studies investigated the effects of light intensities above 10.8 lux. A study conducted by Newberry et al. (1988), compared the effects of light intensity on broiler performance (180 lux vs 6 lux). Broiler activity was significantly decreased under the dim lighting, but feed consumption, BWG, and F:G, were unaffected by light intensity. In an earlier trial, Newberry et al. (1986), compared 0.1, 0.5, 1, 10, 20, 30 and 100 lux intensities in 2 different experiments. These trials also found no differences in BWG, however they indicated an increase in feed consumption as light intensity increased ( $P < 0.05$ ).

Little research has been done on LED lighting and its effects upon bird performance and, health, and behavior. Rozenboim et al. (1998, 1999, and 2004) conducted LED light trials with both layers and broilers. No detrimental effects on bird performance resulting from LED light were found. Previous research at the Kansas State University poultry farm had found increasing intensity of LED light had significantly increased BWG in broilers. The intensity in the previous trial had been 5, 10, 15, 20, and 25 lux in the chicks' pens. In this trial, intensity was increased out to 40 lux to investigate further.

Skinner-Noble et al. (2005), explored the effect of feed form on performance and behavior of broilers. It was found that broilers fed pellets showed better performance and spent less time consuming feed than those fed crumbles. The current trial is a combination study of the

effect of LED light intensity and feed form on broiler behavior as well as BWG, and bird performance. Pen light intensities were set to 10, 20, 30, and 40 lux. The objective was to determine the effect of LED light intensity and feed form on broiler behavior, gains, feed conversion, and BWG variation.

## **Materials and Methods**

All broilers were raised following protocols established by Kansas State University Institution of Animal Care and Use. Experiments were conducted at the Thomas B Avery Poultry research unit. Twelve hundred eighty Cobb 500 broiler chicks were used in this experiment. All chicks were randomly chosen and placed in 1.52 x 3.66 meter pens with 40 birds/pen and 4 pens/treatment. Broilers were raised under continuous white LED lights set at 1 of 4 different light intensities: 10, 20, 30, and 40 lux. Black plastic was suspended between each pen to prevent stray light from interfering with neighboring pens. The light lamps were hung at 4 ft above the litter, creating a ring of light over the feeder and water. Due to LEDs being a very directional type of lighting, the rest of the pen was not directly illuminated. For the first 3 days, incandescent house lighting was used in addition to LED lights to allow the chicks to adjust to their surroundings. From 0-3 weeks (the starter phase) all birds were fed a crumbled starter corn/soy diet and from 3-6 weeks (the grower phase) they were fed a grower diet of two different feed forms; crumbles or pellets. Feed and water were provided *ad libitum*. Behavior under each different light intensity was observed and each pen was observed for approximately 10 min each week during the study period. Scan sampling with 1 minute intervals were used to determine how many birds were lying, standing, eating and drinking at each sample time. The number of broilers performing each behavior were averaged over the 10 min sample period. Pen averages were determined for the starter phase and the grower phase. Body weight gain was measured at

3 weeks of age using pen averages but at 6 weeks broilers were weighed individually providing a way to compare body weight variation.

### **Statistical Analysis**

The GLM method, 2 x 4 factorial, and least square comparing means test procedures were run using SAS<sup>(1)</sup> Four tests were conducted to determine broiler body weight normality: Shapiro-Wilk, Kolmogorov-Smirnov, Cramer-von Mises, Anderson-Darling. A difference was said to be significant when  $P < 0.05$ .

### **Results & Discussion**

It was found that body weight gains were not statistically affected by light intensity or feed form (Table 3.1). However, feed form resulted in statistically improved F:G ratios at both 3-6 and 0-6 weeks. Others have observed that it takes less effort for broilers to consume pelleted feed than crumbled feed, which could be the reason for the improved conversion rates. (Skinner-Noble et al. 2005.) It was observed that broiler activity was not statistically affected by feed form. However, in the starter phase, eating behavior was observed to be greater ( $P= 0.0447$ ) under 40 Lux than the other three light intensities (Figure 3.2). Although not statistically different, the broilers raised under 40 lux also spent more time standing, drinking, and less time lying down than did those under the other intensities. This supports the theory that brighter light increases broiler activity. Variability from 3-6 weeks was also calculated using tests for normality (Figure 3.3). The data indicates that broilers given pelleted feed had greater variation in body weight than those fed crumbles. This could have been due to pellet quality. Poor quality pellets used in the current trial were found to break down after abuse and flowing through feeder. The larger, more aggressive broilers could have occupied the light space, eaten all the high

1) Version 9.0 provided by SAS Institute Inc. Cary, NC.

quality pellets, and left the poor quality disintegrated pellets in the feeder for the smaller birds, causing a further separation in body weights.

Due to the nature of LED light being directional, and our lack of knowledge on the effect of LED light on broilers, further investigations need to be conducted to examine performance and behavior. In this trial, the results indicate that lower light intensities did not have any negative effects on body weight or performance. Therefore, it might benefit commercial broiler producers to take advantage of the energy savings by raising broilers under low levels of light. The results of this trial agree with much past research Cherry and Barwick, (1962), who stated that light intensities beyond 10.8 lx (lux) were unnecessary for raising broilers and could depress growth. Also as Newberry et al. (1988), found before, this trial shows that lower levels of light, decrease broiler activity.

**Table 3.1 The Effect of LED Light Intensity on Feed to Gain Ratios in Chicks Fed Pellets and Crumbles From 0-6 Weeks.**

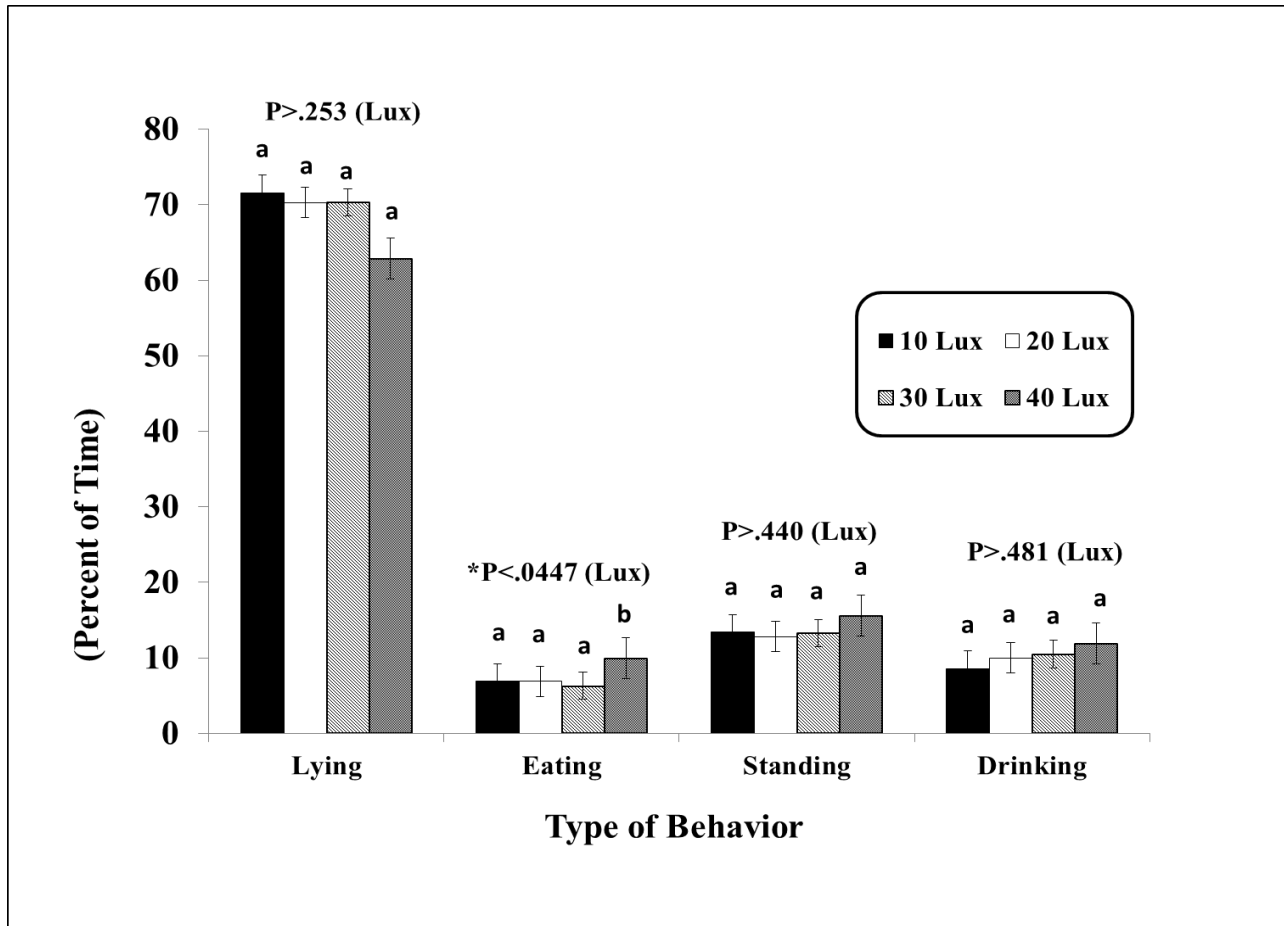
Light Intensity (Lux)	Feed to Gain With Pellets	Feed to Gain With Crumbles
10	1.72± 0.0392	1.76± 0.0392
20	1.68± 0.0392	1.79± 0.0392
30	1.72± 0.0392	1.83± 0.0392
40	1.73± 0.0392	1.73± 0.0392

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P> .682 (Effect of Light Intensity)  
P< .022 (Effect of Feed Form)  
P> .371 (Effect of Light Intensity\*Feed Form)

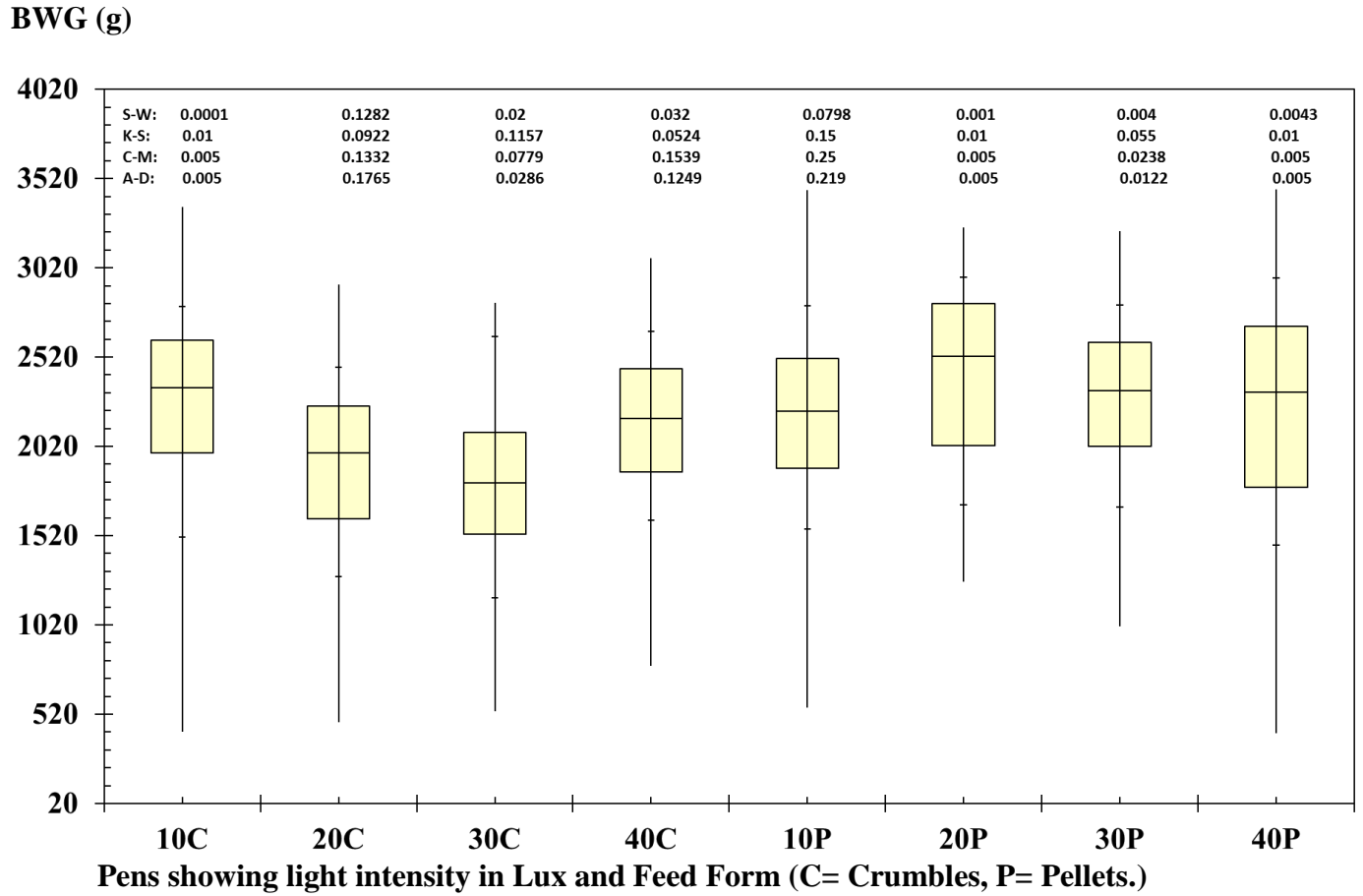
Above performance averages analyzed using GLM Method and LS means.

**Figure 3-1. The Effect of LED Light Intensity on Broiler Behavior During Starter Phase.**



Above means analyzed using GLM Method, and least square comparing means. \*Values with different letters (a,b) differ significantly ( $P < .05$ ).

**Figure 3-2. Box and Whisker Plot of Variation and Normality of Individual Bird Weight in Grams Comparing Light Intensity and Feed Form.**



4 tests were conducted to determine normality in variability: S-W (Shapiro-Wilk), K-S (Kolmogorov-Smirnov), C-M (Cramer-von Mises), A-D (Anderson-Darling). Values of  $P < .05$  suggest abnormality in variation of body weight gains.

## **Chapter 4 - Broiler Preference for Light Color and Feed Form during Feeding**

### **Abstract**

Little research has been conducted to determine broiler chick preference for lighting. Studying bird preference is important in improving comfort and welfare for broilers and it may be beneficial for improving performance. Forty newly hatched Cobb 500 male broiler chicks were grown in floor pens on fresh litter to 42 d of age. Incandescent house lighting was used throughout the duration of the trial. Small, 40.5 × 40.5 cm wooden boxes were constructed and served as additional feeders to help the birds become adjusted to using them as a feed source. The boxes had a single opening in front with a full bottom, top, and three sides. Holes were drilled in the top of the boxes and 25 W incandescent light bulbs were positioned inside. A pen 3.05 meters long and 1.62 meters wide was constructed and the boxes were placed together at one end. On test days (1-3 weeks), blue, green, red, or white light bulbs were placed in the 4 individual box feeders. Light preference trials were repeated weekly. Light intensities were measured and adjusted so that all were equal. Chicks were taken off of feed for 3 h prior to testing and then placed on the runway in pairs, and allowed to choose which light color they preferred during feeding. A choice was recorded when the bird attempted to obtain feed. From 4-6 weeks, blue, green, red, or white light bulbs were still offered as light color choices, but the broilers were also given an additional choice of either pelleted or crumbled feed, and eight total boxes were used. A chi square goodness-of-fit test was used to analyze frequency of broiler choice. From 1-3 weeks it was shown that the broiler chicks preferred white light ( $P < 0.01$ ), with red as the 2<sup>nd</sup> light color of preference. From 4-6 weeks the broilers indicated a preference ( $P < 0.01$ ) for pelleted feed and the preference for light color remained the same as weeks 1-3.



Our data concluded that chicks have a preference for white or red light and pelleted feed form during feeding.

## **Introduction**

Currently in the poultry industry, increasing competition and rising energy costs are forcing broiler producers to find ways to minimize the cost of growing broilers. Management strategies have been developed to apply today's technology to minimize lighting costs. Dim lights and blue and green lighting, are examples of strategies currently being used to increase broiler performance. Past research has shown that broiler chicks have been shown to prefer the color red and complex floor pattern designs (Taylor et al. 1969; Berryman et al. 1971). Heshmatollah (2007) found that broilers had no preference when given different light intensities but they prefer green light when compared to red, orange, or yellow. The authors also concluded that broiler chicks preferred an orange dyed feed under low light levels, but green dyed feed under higher light levels. The current experiment investigates bird preference for light color during feeding, comparing 4 basic colors: green, blue, red, and white under common light intensity levels. It is known that broilers can have better feed conversion when fed pelleted feed vs. crumbles (Skinner-Noble et al. 2005). This trial also investigates broiler preference for feed form during the grower phase. During the first few days in a young chick's life it is critical for them to obtain feed, readily or easily in order to maximize growth rates. Knowing what broiler chickens prefer for light color can be of help to producers in trying to get the chicks to consume more feed. Also, from a welfare standpoint it is important to provide the chicks with a comfortable environment to reduce stress and maximize performance. Choosing a preferred light color is important for maximizing health and performance. The objective of the study was to determine broilers' preference for light color and feed form during feeding.

## Materials and Methods

All broilers were raised following protocols established by Kansas State University Institution of Animal Care and Use. Experiments were conducted at the Thomas B Avery Poultry research unit. Both flock and individual chick preference was investigated. Forty newly hatched Cobb 500 male broiler chicks were grown on fresh litter to 42 d of age. Incandescent lighting was used throughout the duration of the experiment, and all pens were given *ad libitum* access to feed and water. The chicks were leg banded on d 2 for identification. Small, 40.5 x 40.5 sq. cm wooden feeder boxes were constructed and provided constant access for the chicks. The boxes had a single opening in front with a full bottom, top, and three solid sides. Holes were drilled in the top and colored incandescent bulbs<sup>(1)</sup> were positioned in the top of the box during test days (one bulb per box). White, incandescent 25 W Philips light bulbs were used to light up all the boxes in the floor pens on non-test days. Boxes were placed in the floor pens and were used as feeders throughout the duration of the trial allowing the chicks to become acclimated to them. Chicks were also fed daily in Choretime pen feeders ensuring that feed would not run out. Feed and light preference evaluations were conducted weekly. A runway 3.05 meters long and 1.62 meters wide was constructed and boxes were placed together at the end, opposite the pedestrian walkway. From 1-3 weeks, red, white, blue, or green light bulbs were placed in the 4 individual box feeders (Figure 4-3). Light intensities were measured and adjusted with a light meter<sup>(2)</sup> to ensure equality. Light intensity was kept at 50 lux at feed level inside the feeder boxes on test days to ensure that lights were bright enough that birds could see the differences in light color. Chicks were taken off of feed for 3 hours before the test. They were then placed on the runway in pairs,

- 1) Philips 25 W Party and Decorative bulbs
- 2) model # FSC-06-662-64 Fisher Scientific

and then allowed to walk toward the light color they preferred during feeding. A light color selection was recorded the moment the bird attempted to obtain feed. Four replications occurred resulting in 160 total runs. If a broiler chick did not make a choice within 5 minutes it was recorded as undecided. Once a bird made a decision it was caught and put back in the holding tubs until it was time for the next run. It was managed so that broilers did not make group decisions and choices were recorded on an individual level. In between runs, light colors were rotated so that it would be certain chicks were choosing light color and not the location of the feeder box.

From 4 to 6 weeks, red, white, blue, and green light were still offered for color choice but a second option was introduced: pelleted or crumbled feed. Eight total boxes were used in which both crumbled and pelleted feed were available under each of the light colors, red white, blue, and green. Broilers were fed crumbled feed on non-test days. During the test was the first time they were exposed to pelleted feed. Again light colors were rotated and re-adjusted to 50 lux in between each run.

### **Statistical Analysis**

The GLM method, proc freq, and least square comparing means test procedures were run using SAS.<sup>(1)</sup> A chi square goodness-of-fit test was used to analyze frequencies of broiler light color and feed form choice. A difference was said to be significant when  $P < 0.01$ .

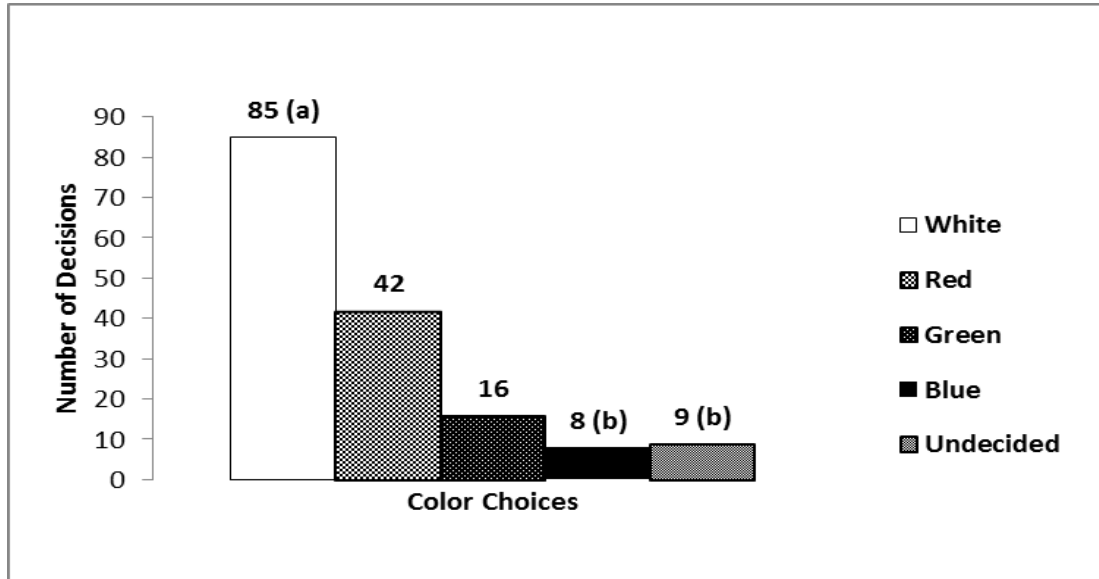
### **Results & Discussion**

During weeks 1 to 3, birds showed a preference for white light and chose not to feed under blue light ( $P < 0.01$ ) (Figure 4.1). Red was the second color choice of preference. From weeks 1 to 3, preference for white light increased while preference for red light decreased. From weeks 1 to 3,

(1) Version 9.0 provided by SAS Institute Inc. Cary, NC.

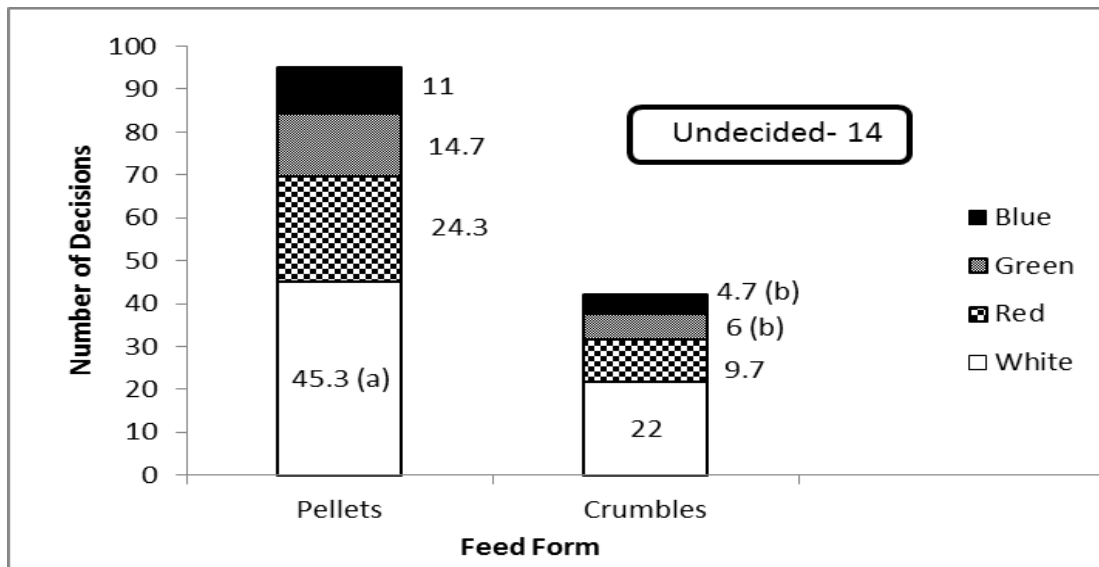
a small number of chicks were observed to be undecided. From weeks 4 to 6, the chicks demonstrated a preference for pelleted feed and white light. ( $P < 0.01$ ) They chose not to feed under green or blue light with crumbled feed. Red remained the second color choice of preference and the number of undecided broilers was larger than during weeks 1 to 3, but still relatively small (Figure 4.2). It was observed during testing that some broilers developed a fear of consuming feed on the runway. Although hungry, some broilers would look at feed, but refuse to peck at it. This was assumed to be from learned fear of being caught after choosing to eat feed under a light color. Using fresh chicks each week could be one way to improve data collected from preference studies such as this one. The data indicates that broiler chicks do show a preference during feeding both for lighting and feed form. A possible explanation as to why broilers prefer to consume feed under white light could be because it helps them identify texture differences they cannot see under different colors. Adopting a strategy allowing broiler chicks to feed under white light and rest under blue or green light (which is typical in the industry) would be relevant for animal comfort and may benefit performance. More research needs to be conducted further investigating these possibilities. Studying broiler preference under different light colors, regimes, and intensity is something that needs to be conducted. Broiler welfare is increasingly becoming important to consumers who prefer that birds are raised in improved and comfortable conditions. Allowing broiler chicks to have the light and feed form that they prefer, could be more comfortable for broilers. This could help improve welfare as well as broiler performance.

**Figure 4-1. Broiler Chick Preference Response to Light Color Choice During Starter Period (weeks 1-3).**



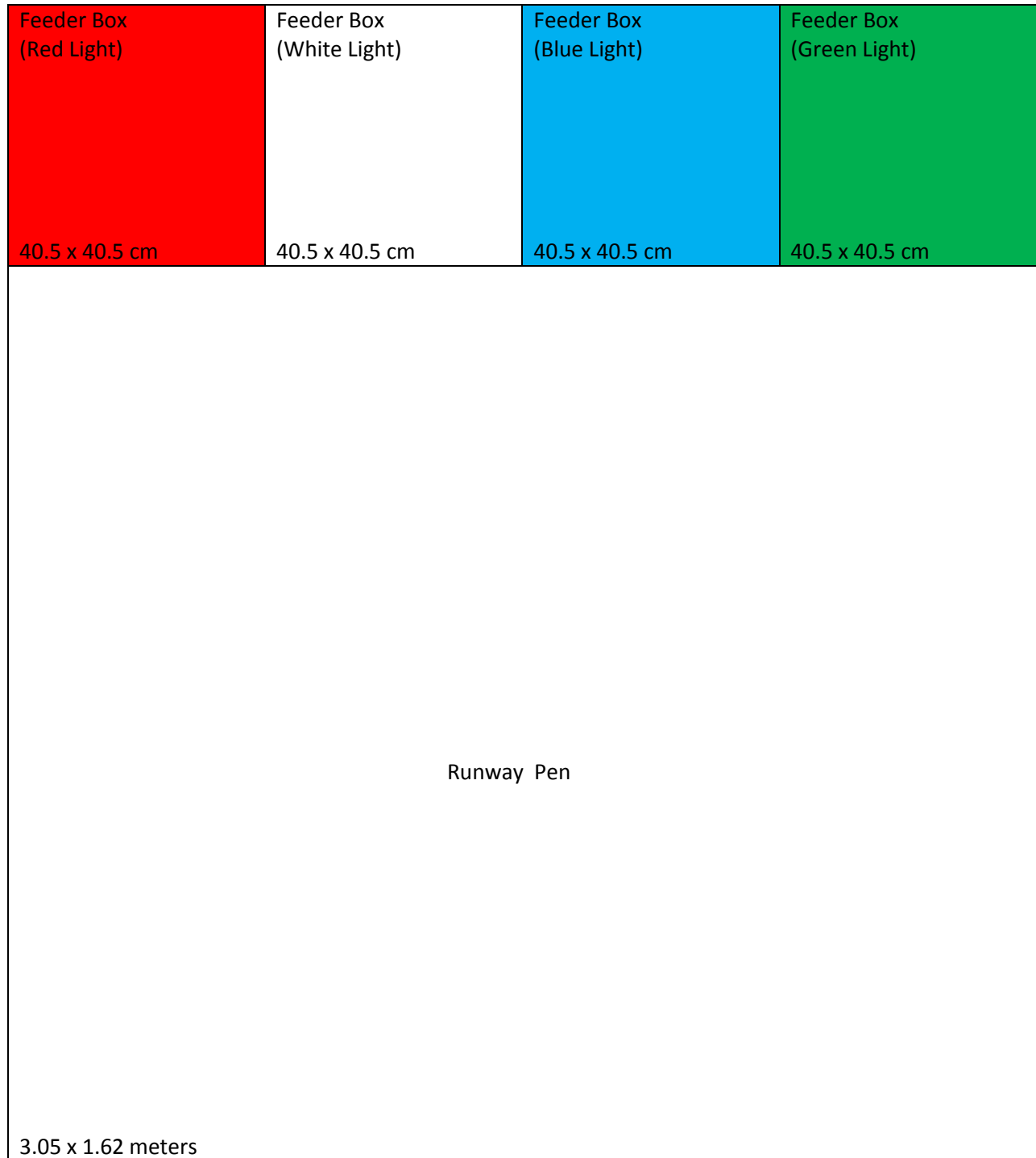
160 total decisions were made and classified. Means for color choice shown. Chi square goodness-of-fit test used to analyze frequency of broiler chick choice (a) indicates statistical significance ( $P < .01$ ) greater than expected value (chicks show preference). (b) indicates statistical significance ( $P < .01$ ) less than expected value. (chicks did not show a preference).

**Figure 4-2. Broiler Chick Preference Response to Light Color and Feed Form Choice During Grower Period (weeks 4-6).**



152 total decisions were made and classified. Means for color choice shown. Chi square goodness-of-fit test was used to analyze frequency of broiler choice. (a) indicates statistical significance ( $P < .01$ ) greater than expected value (broilers show preference). (b) indicates statistical significance ( $P < .01$ ) less than expected value. (broilers did not show a preference).

**Figure 4-3. Diagram Showing Experimental Setup 1-3 Weeks for Chick Light Preference During Feeding.**



## **Chapter 5 - Broiler Chick Preference for Feed Color When Managed Under Different Colored Lights**

### **Abstract**

Research that focuses on broiler preference for lighting and feed color is limited. Studying broiler preference is important for improving comfort and welfare for broilers and it may be beneficial for improving performance. The following experiment was designed to examine chicks' preference for feed color relative to light color. Fifty Cobb 500 newly hatched broiler chicks, never exposed to feed, were placed into pens illuminated with different light colors: red, white, blue, green, and yellow. Under each color of light, 5 colored feed choices were offered: red, blue, green, yellow, and the control feed which was a light brown color. Experiments were conducted in a single building using pens that were 1.52 x 3.66 meters in diameter. The pens were separated using black plastic to keep stray light from interfering with neighboring pens. The chicks were grown on the floor on new litter. All chicks were fed a standard NRC corn soy starter diet and all pens were given *ad libitum* access to feed and water. There were 5 total pens with 10 chicks per pen. The chicks were placed under the lights, and allowed to choose which color of feed they preferred. When a chick made an effort to obtain feed (1 or 2 pecks) the selection was documented. If a chick did not attempt to obtain feed within 5 minutes, it was recorded as undecided. Dimmers were installed in each pen to allow ease of adjusting light intensities. All pens were set at 50 lux. Statistics were analyzed using SAS 9.0 and logistic tests were used to compare the effect of light color. A chi square goodness-of-fit test was used to compare feed color choice frequencies to the 0.05 level of significance. It was found that results were statistically different when comparing light color to light color (green light to blue light, and green light and yellow light). Under blue light, chicks had a statistical

preference for red feed. It was shown that under a green light, chicks did not show a preference for blue feed, but under red light they showed a preference for the control feed (light brown).

## **Introduction**

The environment birds experience may have strong influence on performance and profitability of the flock. Little research has been conducted on bird preference for light color and feed color. It is critical that day old chicks obtain adequate feed on their first day, therefore defining what birds prefer is important. This could increase interest in feeding on the first day.

Taylor et al. (1969) tested color preferences of broiler chicks. They placed one day old chicks in a rectangle box (runway). They placed one colored insert in one side of the box and the other colored insert in the opposite end. If a bird moved to one end or the other, this indicated preferring one color over another. The chicks showed a clear preference of red over blue and also yellow over blue. Heshmatollah (2007) found that broilers had no preference when given different light intensities, but they prefer green light when compared to red, orange, or yellow. The authors also concluded that broiler chicks preferred an orange-dyed feed under low light levels, but green-dyed feed under higher light levels.

Many production facilities in the current industry are using colored light in their grower barns. Blue and green are the most common. However, when feed is dyed red under green or blue light, the eye does not perceive it the same way as under white or red light. In this trial chick preference and perception of feed color under different light color was observed. The objective of the study was to determine broiler preference for feed color under different light colors.

## **Materials and Methods**

All broilers were raised following protocols established by Kansas State University Institution of Animal Care and Use. Experiments were conducted at the Thomas B Avery



Poultry research unit. Fifty newly hatched Cobb 500 male broiler chicks were placed in pens (10 per pen) under different light colors: red, blue, green, yellow, and white. The light bulbs used were Philips 100 W Colortone Outdoor Floodlights. Under each light color they were offered four different colors of feed plus the control feed: red, blue, green, yellow, and light brown (control). Feed was mixed and food coloring was added until desired color was reached. Feed crumbles were placed in small black feeding pans directly under the colored light. Each of the test feeds were positioned in a circle around birds. Chicks were placed in pairs in the center of the circle, and then were allowed to choose which feed color they preferred (Figure 5-1). A choice was recorded the moment the bird attempted to obtain feed. It was managed so that birds did not make group decisions. Choices were recorded on an individual level, and if necessary, birds were tested a second time during some runs to ensure individual decisions were made.

Four replications were conducted resulting in 200 total runs. Black plastic slating was placed between pens to keep stray light from interfering with neighboring pens. Each pen was approx. 1.52 m wide, 3.66 m long, and 1.83 m high. The chicks were raised to 3 weeks of age and then body weights were recorded. The chicks were placed into the feeding circle facing different directions each time so that initial direction would not interfere with feed choice. If a chick did not make a choice within 5 minutes, it was recorded as undecided. The chicks were grown on fresh litter. Each pen of birds were raised under different light colors, and light intensities were measured and adjusted with a light meter<sup>(1)</sup> so that all were equal. All chicks had never been fed before trial initiation and had experienced a 6 hour ride to the poultry farm from the hatchery.

1) model # FSC-06-662-64 Fisher Scientific.

## **Statistical Analysis**

The Proc Logistic procedure in SAS<sup>(1)</sup> was used to compare light colors. Chi square goodness-of-fit test was conducted for each light color using the proc freq procedure to compare feed color choice frequencies to the 0.05 level of significance under each different light color. The least square comparing means test was also run.

## **Results & Discussion**

When growing commercial broilers it is important that young chicks locate and eat feed on their first day in the poultry barn (Sklan 2001). Implementing a strategy using colored feed during the first few days could help chicks locate and consume more feed. The light intensity under each colored light was set at 50 lux. This is a brighter intensity than is used in many poultry houses, but it was important that the light be intense enough so the chicks could see the feed well to make a decision. Also, broilers were grown to 3 weeks of age in this trial, and preference runs were attempted at weeks 1, 2, and 3, but due to a very high number of undecided chicks only the data from the 1<sup>st</sup> day was kept and analyzed.

In this trial, when comparing the results of light color to light color, it was found that green light differed from blue light ( $P < 0.05$ ). Under blue light the birds showed a high preference for red dyed feed. (Table 5.1, 5.2). A difference is also shown when comparing green light to yellow light because chicks had more choices for green feed under yellow light and a very low number of chicks were undecided under yellow light ( $P < 0.05$ ) (Table 5.1, 5.2). The other comparisons among light colors were not significant. For the feed color analysis, chicks preferred red feed over other feed colors when under blue light ( $P < 0.05$ ) (Table 5.3). A trend was also observed that under green light chicks did not prefer blue feed. Additionally, there was

(1) Version 9.0 provided by SAS Institute Inc. Cary, NC.

another trend that showed that when under red light chicks preferred the control feed. This data indicated that certain lights could cancel out the effect of having the right color of feed. For example, red feed under blue or yellow light, no longer appears red as it does under white light.

From the results of this trial, a producer using blue lights in their production houses might consider adding red dye to the feed at least during the first few days to try to increase consumption. This could potentially help with mortality, broiler chick health, welfare, and overall performance during the starter period. More research needs to be done in this area to investigate the effects of colored light and colored feed as well as chicks' preference at a later age.

**Table 5.1 Chick Preference Response to Feed Color Under Different Light Colors**

Light Color	Broiler Chicks Feed Color Choices Shown in Percentages					
	Red Feed	Green Feed	Blue Feed	Yellow Feed	Control	Undecided
Red Light	12.5	15.0	20.0	15.0	32.5	5.0
Green Light	20.0	10.0	5.0	12.5	25.0	27.5
Blue Light	42.5	7.5	20.0	12.5	12.5	5.0
Yellow Light	17.5	27.5	17.5	22.5	12.5	2.5
White Light	27.5	20.0	12.5	10.0	12.5	17.5

**Table 5.2 Overall Statistical Comparison of Broiler Chick Feed Color Choice Comparing Light Colors**

Contrast	Chi-Square	Pr > Chi-Square
Red vs Green	9.5058	0.0905
Red vs Blue	10.1135	0.0721
Red vs Yellow	6.0235	0.3039
Red vs White	9.2304	0.1002
Green vs Blue	12.8029	0.0253*
Green vs Yellow	13.2868	0.0208*
Green vs White	5.5358	0.3540
Blue vs Yellow	9.3699	0.0952
Blue vs White	6.5645	0.2551
Yellow vs White	6.7444	0.2404

Data analyzed using logistic tests comparing the effect of light color. \*Significantly different ( $P < .05$ ). Use percentage table to compare feed color choices under different light color when statistical differences are present.

**Table 5.3 Statistical Comparison of Each Feed Color Offered Under Each Different Light Color**

Light Color	Feed Color Choice	Chi- Square	Total Chi- Square (Per Light Color)	P Value (Per Light Color)
Red	Red	0.4167	10.1	0.07245
Red	Green	0.0667		
Red	Blue	0.2667		
Red	Yellow	0.0667		
Red	Control	6.0167		
Red	Undecided	3.2667		
Green	Red	0.2667	9.5	0.09071
Green	Green	1.0667		
Green	Blue	3.2667		
Green	Yellow	0.4167		
Green	Control	1.6667		
Green	Undecided	2.8167		
Blue	Red	16.0167	22.4	0.00044*
Blue	Green	2.0167		
Blue	Blue	0.2667		
Blue	Yellow	0.4167		
Blue	Control	0.4167		
Blue	Undecided	3.2667		
Yellow	Red	0.0167	8.9	0.11312
Yellow	Green	2.8167		
Yellow	Blue	0.0167		
Yellow	Yellow	0.8167		
Yellow	Control	0.4167		
Yellow	Undecided	4.8167		
White	Red	2.8167	5.0	0.41588
White	Green	0.2667		
White	Blue	0.4167		
White	Yellow	1.0667		
White	Control	0.4167		
White	Undecided	0.0167		

\* Significantly Different ( $P < .05$ ). P-value per light color shows if broiler chick choice of feed color within a light color was significantly different (meaning the chicks had a statistical preference) or not significant (meaning the chicks didn't have a statistical preference).

**Figure 5-1. Photo of Chicks on Day 1 Showing Experimental Set-up.**



1 day old chicks were placed under light and allowed to choose which feed color they preferred.

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