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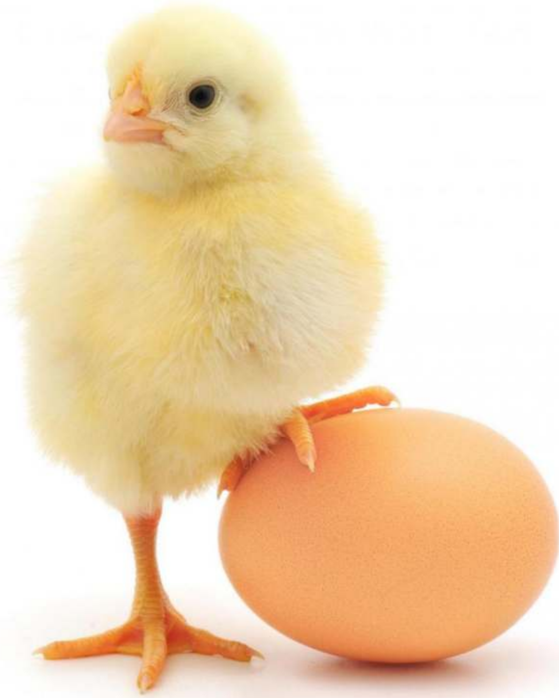

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A Review of Lighting Programs for Broiler Production

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Abstract: Genetic selection of broilers for rapid growth has resulted in greater final BW and improved feed conversion efficiency in reduced time increments. However, accelerated growth rates are associated with several undesirable traits, including increased fat deposition, and higher incidence of metabolic diseases, visual anomalies, skeletal deformities, and circulatory problems. These deficiencies, as well as the associated financial losses, have led to increased interest in developing management techniques that will maximize productivity while minimizing associated problems of broilers. Light is an important parameter of poultry production. Currently, there are a wide variety of lighting programs (wavelength, intensity, and duration) and devices available to poultry producers, each possessing its own characteristics and applicability to rearing poultry. The potential for changing photoperiods to influence broiler productivity and health is receiving considerable investigation. Some lighting programs have a central purpose of slowing the early growth rate of broilers thus allowing birds to achieve physiological maturity before maximal rates of muscle mass accretion. The aim of this review is to update research on lighting programs for broiler production and to give direction for future lighting research.

Key words: Light intensity, light duration, constant light, intermittent lighting, light wavelength, broiler

Introduction

Lighting is a powerful exogenous factor in control of many physiological and behavioral processes. Light may be the most critical of all environmental factors to birds. It is integral to sight, including both visual acuity and color discrimination (Manser, 1996). Light allows the bird to establish rhythmicity and synchronize many essential functions, including body temperature and various metabolic steps that facilitate feeding and digestion. Of equal importance, light stimulates secretory patterns of several hormones that control, in large part, growth, maturation, and reproduction.

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

The purpose of this paper is to review light as it relates to broiler production and welfare. Light as an environmental factor consists of three different aspects: intensity, duration, and wavelength. Light intensity, color, and the photoperiodic regime can affect the physical activity of broiler chickens (Lewis and Morris, 1998). The increased in physical activity can stimulate bone development, thereby improve the leg health of birds. Each of these aspects will be discussed relative to rearing broilers.

The broiler producer must consider several critical factors in the design of a lighting program. Housing type is the first concern. In the United States, both dark and light colored curtains are common in broiler production facilities. However, clear curtained sidewall housing prevails in most of the rest of the world. Broiler producers with clear curtains and/or open sidewall houses are restricted in lighting alternatives and are forced to design lighting programs around the limitations of natural daylight/length. Houses with dark curtains or solid sidewalls allow the producer to establish lighting systems that control intensity, duration, and wavelength throughout the entire grow-out period.

General concerns: When considering lighting programs as a management tool, both light intensity and duration are factors that are normally considered. In most situations, light provided by incandescent sources is used. In the United States, a typical broiler lighting program might consist of a minimum light intensity of 20 lx provided continuously during the early part of

[3]Mention of trade names or commercial products in this publication is soley for the purpose of providing specific information and does not imply recommendation or endorsement by the USDA.

the grow-out period, i.e., 1-7 d post-hatch. Continuous lighting at around 20 lx will ensure that chicks acclimate properly to their environment, as indicated by optimal feed and water intakes. Following the early period, restriction of both light intensity and duration is usually implemented. It is common for intensity to be from 3 to 5 lx and duration from 2 to 6 h/d for the remainder of the grow-out period.

This example is not meant to suggest that lighting programs are standardized in the United States or around the world. On the contrary, lighting programs vary greatly; however, researchers and producers alike recognize the need for systematic studies of lighting programs.

Genetic selection has resulted in high yield broilers that can attain market weight in reduced time based on fast growth rates and improved feed conversion. However, rapid and accelerated growth has resulted in several health and welfare concerns. Of particular concern are diseases and anomalies of the skeletal and circulatory systems. It is not uncommon for more than 2% of broilers to be condemned or down-graded during processing as a result of leg abnormalities (Morris, 1993). The genetic potentiality of broilers would not be utilized fully due to environmental constraint. Therefore, an improvement of the production and its efficiency solely depends on the quality of the environmental management. There is little question that light is crucial to incidences of diseases attributed to fast growth. Decreased photoperiods are reported to decrease susceptibility to metabolic diseases such as ascites associated with pulmonary hypertension syndrome, sudden death syndrome, tibial dyschondroplasia and other skeletal disorders (Classen and Riddell, 1989; Classen *et al.*, 1991; Renden *et al.*, 1991; Petek *et al.*, 2005). Additionally, intermittent lighting programs can reduce lameness and circulatory problems in broilers and roasters (Buckland, 1975; Ononiwu *et al.*, 1979; Simmons, 1982; Wilson *et al.*, 1984; Renden *et al.*, 1991, Kritensen *et al.*, 2004). Behavioral evaluations utilizing radar equipment have revealed that broilers exposed to intermittent lighting are more active during the light periods (Simmons, 1982; Simmons and Haye, 1985). Finally, intermittent lighting programs have shown increased livability and decreased leg problems, mortality and incidence of circulatory diseases (Ononiwu *et al.,* 1979; Classen and Riddell, 1989).

Lighting intensity: Broiler behavior is strongly affected by light intensity. Generally, brighter light will foster increased activity, while lower intensities are effective in controlling aggressive acts that can lead to cannibalism. Producers regularly use modern electronic systems to increase light intensity for short periods during grow-out to increase exercise and thereby reduce skeletal and metabolic disorders. Research literature, however, portrays conflicting evidence concerning the effects of light intensity on the normal activity levels of chickens. Newberry *et al.* (1985) reported increased activity in brighter (6 to 12 lx) vs. darker (0.5 lx) areas within pens. It should be noted that in this study the chicks were subjected to changes in light intensity over time. A subsequent study, Newberry *et al.* (1986) used constant light intensity treatments that ranged from 0. 1 to 100 lx. Results suggested that as light intensity increased, activity was decreased with each incremental increase in age. Charles *et al.* (1992) observed an increase in BW when broilers were grown under a light intensity of 5 lx. Low intensities have been associated with reduced walking and standing, as well as with decreased incidences of fighting, feather pecking and cannibalism (Buyse *et al.*, 1996). Field studies have generally shown that higher light intensities (in excess of 5 lx) decrease BW due to increased activity. These studies indicated a reduction in the incidence of skeletal disorders such as tibial dyschondroplasia and enlarged hocks.

Most modern lighting programs begin with a high light intensity (~20 lx) that is decreased to around 5 lx by 14 to 21 d and then maintained at 5 lx or less for the remainder of the grow-out period. Such programs have been implicated in structural changes in eye morphology. Since broilers are commonly reared in dim and near-continuous lighting, it is possible that a large number of birds in commercial production may suffer from light-induced changes in eye morphology. Research indicates the extremely low light intensities (less than 5 lx) can cause retinal degeneration, buphthalmos, myopia, glaucoma and damage to the lens leading to blindness (Buyse *et al.*, 1996; Cummings *et al.*, 1986; Ashton *et al.*, 1973; Chiu *et al.*, 1975; Li *et al.*, 1995).

Preference studies, i.e., providing birds with choices of several lighting intensities have shown that broilers will exhibit preference for light intensity by 6 wk of age. Young chick (1 to 28 d of age) generally preferred brighter light (~20 lx) (Berk, 1995). Another preference study showed that broilers preferred blue or green light over red or white light (Prayitno *et al.*, 1997).

Light duration: Lighting duration, i.e., photoperiod, is the second major aspect of light that will alter broiler performance. Most research involving light management has focused on this factor. Different photoperiodic regimes have been applied and tested over the years, while almost all of them have been shown to improve broiler welfare with conventional near-continuous lighting (Gordon, 1994). Lighting duration is largely dependent upon the age of chickens involved and type of housing in use. Research and discussion continue in an attempt to define the optimal photoperiodic regime

Table 1: Sample lighting program recommendation*

Age (days)	Light Intensity (lx)	Photoperiod (L= Light, D= Dark) (Broiler)	
0-7	20	23.0L:1.0D	23.0L:1.0D
8-14	5	16.0L:8.0D	16.0L:8.0D
15-21	5	16.0L:3.0D:2L.3D	(d 15-35) Light increased 2h/wk
22-28	5	16.0L:2.0D:4.0L:2.0D	(d 36-42) 23.0L:1.0D
29-35	5	16.0L:1.0D:6.0L:1.0D	
36-49	5	23.0L:1.0D	

*This lighting program is adopted from Renden *et al.*, 1996

suitable for broiler chickens. However, results to date suggest an absolute minimum uninterrupted dark period of 4 hours should be given, but the requirements for sleep may be higher at certain points of the growing period (Blokhuis, 1983). Table 1 is representative of typical lighting programs in use in environmentally controlled grow out facilities, such as tunnel ventilated houses, that are in wide-spread use in the U.S. Table 2 and 3 are lighting recommendations offered by primary breeders for specific broiler strains.

Darkness: Broiler lighting schedules can be characterized in a number of ways, including the number of h of darkness and how many periods of darkness are included in each 24 h cycle. Research has shown that darkness is as important to growth and health of broilers as light (Classen *et al.*, 1991). It is hypothesized that short photoperiods early in life will reduce feed intake and limit growth. Recent research comparing 12L:12D, 16L:8D and 20L:4D lighting schedules demonstrated clearly that longer periods of darkness prevent regular access to feed and consequently reduce feed intake and limit growth (Classen, 2004a). Furthermore, Classen *et al.* (2004b) also compared lighting programs with 12 h of darkness per each 24 h period provided in 1, 6, or 12 h intervals. Their study indicated that early growth rate was significantly reduced by longer periods of darkness, but gain from 14 to 35 d, as well as final body weight were not affected by lighting programs. Feed conversions were higher for 12L:12D and two 6L:6D periods per each 24 h period than 12 (1L:1D) periods per each 24 h period. The 12L:12D treatment resulted in lower mortality than the 12 (1L:1D) treatment and the 2 (6L:6D) was intermediate.

Gait scoring has been proposed as an indicator of leg health and consequently broiler welfare (Sanotra *et al.*, 2002; Garner *et al.*, 2005). Broilers reared under a 2 (6L:6D) until 33 d of age showed higher gait scores, thus more leg problems and poorer general welfare, than broilers reared under a 12 (1L:1D) schedule (Garner *et al.*, 2005). In general, longer dark periods were associated with lower mortality and improved gait scores. Reduced early growth which increased leg strength was proposed as the rationale of this effect.

Broilers reared under longer periods of darkness are reported to experience better health than counterparts under long daylight conditions. Several physiological explanations can be offered. Melatonin is a hormone released from the pineal gland that is involved in establishing circadian rhythms of body temperature, several essential metabolic functions that influence feed/water intake patterns and digestion, and secretion of several lymphokines that are integral to normal immune function (Apeldoorn *et al.*, 1999). Daily dark periods are necessary to establish normal secretory patterns of melatonin. Melatonin, which is synthesized in the pineal gland and retina of birds, is released during the hours of darkness in response to the activity of serotonin-N-acetyltransferase, the enzyme that catalyzes the synthesis of melatonin in both the retina and pineal gland (Binkley *et al.*, 1973). Birds provided with sufficient dark periods have fewer health related problems, including sudden death syndrome, spiking mortality and leg problems than those maintained in continuous or near continuous light (Apeldoorn *et al.*, 1999; Moore and Siopes, 2000). Livability, average BW, feed conversion rate, and percentage condemnations were improved in broilers exposed to restricted photoperiods, as compared to broilers subjected to continuous light (Classen *et al.*, 1991; Classen, 2004a). Broilers on intermittent photoperiods exhibited less stress, as measured by plasma corticosterone (Buckland *et al.*, 1974; Puvadolpirod and Thaxton, 2000a-d), than counterparts on continuous light. Plasma corticosterone is known to be elevated in stressed broilers (Puvadolpirod and Thaxton, 2000a-d; Olanrewaju *et al.*, 2006). Increased heterophil:lymphocyte ratio is an accepted indicator of stress in chickens (Siegel, 1995). Broilers reared under continuous light had a higher heterophil:lymphocyte ratio and experienced greater fear response, as indicated by increased tonic immobility time, than birds reared under a 12L:12D photoperiod (Zulkifli *et al.*, 1998).

Constant light: When photoperiod is maintained at a constant level throughout the growth cycle of broiler chickens, shorter d length is associated with slower growth (Li *et al.*, 1995). The slower growth rate is a reflection of reduced feed intake associated with shorter d and reduced leg abnormalities (Gordon, 1994). If given a choice, chickens prefer to eat during the photoperiod, although they will eat during darkness if insufficient periods of light are provided (Simmons, 1982). The

Table 2: Lighting program recommendation for Ross x Ross 308*

Age (days)	Light Intensity (lx)	Photoperiod (L = Light, D = Dark) (Broiler)
0-7	30-40	23.0L:1.0D
8-28	10-15	20.0L:4.0D
29-end	3-5	23.0L:1.0D

*This lighting program is adopted from the art of genetic science (Ross Aviagen Brand).

Table 3: Lighting program recommendation for Ross x Ross 708*

Age (days)	Light Intensity (lx)	Photoperiod (L= Light, D= Dark) Broiler
0-7	30-40	23.0L:1.0D
8-21	10-15	23.0L:1.0D
22-end	3-5	23.0L:1.0D

*This lighting program is adopted from the art of genetic science (Ross Aviagen Brand).

length of day required to reduce growth rate has not been defined. Continuous light disrupts the diurnal rhythm and has some welfare concerns. Among those are high prevalence of leg and skeletal disorders in poultry (Sanotra *et al.*, 2001, 2002) and affected birds may even experience difficulty in getting to feed and water (Wong-Valle *et al.*, 1993). In addition, use of continuous or near-continuous light has proved to be stressful and results in greater mortality (Freeman *et al.,* 1981). However, introduction of a moderate day length of 16 h is associated with potential welfare benefits (Gordon, 1994; Davis *et al.*, 1997; Rozenboim *et al.,* 1999b), including lower physiological stress, improved immune response, increased sleep, increased overall activity, and improvement in bone metabolism and leg health (Classen *et al.*, 2004b). Furthermore, lighting schedules also reduce growth-related mortality including sudden death syndrome and improve productivity (Classen *et al.,* 1991; Riddell and Classen, 1992). In addition, birds that are able to maintain an uninterrupted diurnal rhythm are normally able to organize patterns of behavior, such as eating, sleeping, resting and locomotion according to night and day.

Intermittent lighting: Research on intermittent lighting has been extensive but complicated by a wide variety of light-dark cycles and management systems. However, intermittent lighting programs have frequently resulted in superior broiler productivity in comparison to constant light (Classen, 2004a; Rahimi *et al.*, 2005). In addition, intermittent lighting frequently reduces the incidence of leg disorders and has also been shown to reduce sudden death syndrome (Buckland, 1975; Simmons, 1986; Classen and Riddel, 1989). Circadian (daily) rhythms in activity and metabolism are well recognized in diurnal poultry species (Classen, 2004a). Entraining endogenous circadian rhythms can be accomplished by a number of factors such as housing, but light is almost certainly the most important factor. Alternative lighting programs can be classified into intermittent (e.g., 1L:3D repeated, Wilson *et al.*, 1984), restricted (e.g.,16L:8D, Robbibs *et al.*, 1984), combination of intermittent and restricted (e.g., 12L followed by 15 min L:2D repeated over 12 h, Quarles and Kling, (1974), and increasing photoperiod schedules (Classen *et al.*, 1991; Renden *et al.*, 1996). Kuhn *et al.* (1996) observed that male broiler chickens raised in near continuous lighting (23L:1D) and intermittent lighting (1L:3D, IL) repeatedly had higher growth rates, higher plasma growth hormone levels and testosterone concentrations than birds under a continuous lighting (24L:0D) regimen. Charles *et al.* (1992) reported similar results where male broilers subjected to an increasing photoperiod had larger testes and higher plasma androgen concentrations at 7 wk than birds under a continuous light regimen. Chickens reared under increasing photoperiod had higher plasma androgen concentrations at 7 wk compared to those under constant photoperiod, but light intensity had no effect (Charles *et al.*, 1992). Charles *et al.* (1992) concluded that a lighting program beginning with an extended dark period and gradually increasing the day length results in reduced early growth rate, reduced feed intake, improved FCR, compensatory growth, stimulated sexual maturity as early as 7 wk, and improved chicken livability when compared with those exposed to near continuous constant photoperiod program. Potential health benefits associated with increasing photoperiod may result from reduced early growth rate, increased activity, increased androgen hormone production, changes in metabolism, or combinations of these factors (Classen and Riddell, 1989). Ohtani and Lesson (2000) reported that performance of broiler chickens is improved by intermittent lighting of repeated cycles of 1 h light and 2 h darkness schedules compared to continuous lighting. Rozenboim *et al.* (1999a) examined the effect of different light sources and light schedules on the growth of commercial broilers. In their first experiment, birds were reared under 3 light sources: incandescent light bulb, warm-white fluorescent light tube or warm-white mini-fluorescent light bulb. For their second experiment birds were reared on 3 light schedules i.e. 23 h light and 1 h dark (23L:1D) throughout; an increasing light schedule with initial 23L:1D, then 8L:16D increasing daylight gradually to 16L:8D, or an intermittently increasing daylight schedule (16:8I) where light and dark periods were shorter but portioned to achieve the same total hours per day up to 16L:8D. These results revealed broilers reared under mini-fluorescent light bulbs were heavier than those under fluorescent tubes or incandescent bulbs by 49 d. Furthermore, broilers reared under 16D:8L and 16L:8D regimens were heavier than those under 23L:1D at 49 d. In addition, mortality was higher in groups on 23L:1D than on

16L:8D or 16D:8L, and incidence of leg condemnation was higher in the 16D:8L group with lower skin damage than in those on 23L:1D and 16L:8D at 49 d. Conclusions on the importance of metabolic changes with darkness are few but research in this area holds considerable promise.

Color of light: Color is the third major aspect of light. It is dictated by wavelength and it exerts variable effects on broiler performance. None of the commonly used types of fluorescent light emits appreciable amounts of ultraviolet A light (UVA, ë 320-400 nm). Daylight has a relatively even distribution of wavelengths between 400 and 700 nm. Birds sense light through their eyes (retinal photoreceptors) and through photosensitive cells in the brain (extra-retinal photoreceptors). Blue light has a calming effect on birds, while red will enhance feather pecking and cannibalism. Blue-green light stimulates growth in chickens, while orange-red stimulates reproduction (Rozenboim *et al.*, 1999a,b; 2004). Light of different wavelengths has varying stimulatory effects on the retina and can result in behavioral changes that will affect growth and development (Lewis and Morris, 2000). There are four kinds of lamps available to poultry producers: incandescent, fluorescent, metal halide and high-pressure sodium. All four types are in use in poultry facilities for laying hens, breeder flocks, broilers and turkeys. The incandescent bulb is the current standard by which others are compared, especially in broiler production. Incandescent bulbs provide light energy but much of it is electrical energy with a light efficiency of about 8-24 lumens per watt and a rated life of about 750-2000 h (Darre and Rock, 1995). Fluorescent lamps may last more than 20,000 h under poultry house conditions and may decrease their light output by about 20-30 % over their lifetime (Darre, 1986). High pressure sodium lamps release an electric current through a high level of sodium vapor producing energy, but the highest intensity is in the yellow, orange and red regions with longest rated life of all lamps at about 24,000 h (Dare and Rock, 1995; Darre, 2005). They require a warm up time of between 5 and 15 min, which indicates that after a power outage, backup lighting may be necessary until full illumination has been achieved. Metal halide lamps have between 32 and 1,500 watts with three different outer bulb finishes: clear, phosphor and diffuse (Darre, 2005) with light across the entire visible spectrum, they are considered a cool light, having a lot of blue. They have between 80 and 100 lumens per watt and are rated at about 10,000 to 20,500 h of life (Darre, 2005). These lamps also have a warm up period of 5 to 15 min to achieve full illumination.

The four most important visual abilities of poultry are spectral and flicker sensitivities as well as accommodation and acuity (Prescott and Wattes, 1999). Domestic fowl have a number of adaptations to their color apparatus not shared by humans. They possess three photoreceptors compared with just two (rods and cones) receptors in humans (King-Smith, 1971). The additional photoreceptor is a double cone, but its function is not clear, though it does respond to incident light. Birds have four photoreactive pigments associated with cone cell that are responsible for photopic color vision, while humans have only three pigments (Yoshizawa, 1992). The pigments in bird cones are maximally sensitive at wavelengths of 415, 455, 508 and 571 nm, while those of humans are maximally sensitive to wavelengths of 419, 531 and 558 nm (Dartnall *et al.*, 1983). In birds, the proportion of the different cone cell types also varies on the retinal surface. Birds possess colored oil droplets in their cone cells such that incident light is filtered before it reaches the photoreactive pigments. These droplets are associated with individual cone cell species (Bowmaker and Knowles, 1977). The ability of chickens to visualize color is similar to that of humans, but they cannot see as well when exposed to short wavelengths (blue-green). Specific light wavelength may have an impact on production and characteristics of broilers. During the early period, short wavelengths appear to stimulate growth. However, when the bird approaches the time of sexual maturity long wavelengths (orange-red) increase growth and are effective in stimulating sexual hormonal pathways that culminate in fertile egg production.

Growth in broilers is affected by light spectra. Broilers under blue or green light become significantly heavier than those reared under red or white light (Rozenboim *et al.*, 2004). Green light accelerates muscle growth (Halevy *et al.*, 1998) and stimulates growth at an early age, whereas blue light stimulates growth in older birds (Rozenboim *et al.*, 1999a,b; 2004). In addition, circulating thyroid hormones i.e. triiodothronine (T_3) and thyroxin (T_4) are important growth promoters (McNabb and King, 1993) and play a relatively important role in growth inhibition as well as compensatory growth acceleration in broilers (Yahav, 1999). Research completed to date is not sufficient to permit the recommendation of blue light throughout the production cycle of broilers. However, recent studies show that young broilers have a strong preference for bright light (Davis *et al.*, 1997).

Conclusions: Light management is an important component of broiler production. Wavelength and intensity are important in behavioral modifications while exposure of broilers to darkness is essential to bird health. Light management is widely used to improve production efficiency as summarized in Tables 1 to 3. However, it is important to understand how light can affect bird welfare. Restricted lighting schemes use photoperiods light of 16 h and darkness periods of 8 h within a 24 h/d. Intermittent lighting programs often use

1 h of light followed by 3 h of darkness repeated within a 24 h/d, thus providing a total of 6 h of light. Both of these lighting programs are utilized mostly by broiler companies today and permit the birds to experience a dark period allowing rest, melatonin synthesis, and less stress. These lighting programs have a central purpose of slowing the early growth rate of broilers which allows birds to achieve physiological maturity prior to maximal rate of muscle mass accretion. Many broiler companies may not be experiencing the full effect of restricted light regimes because the programs are not applied consistently. The literature indicates that restricted lighting programs enhance broiler production through improvements in BW, FCR, immune status, and better health as a result. Much is known about the effects of the lighting on production, but how the welfare of the birds may be affected is lacking. To assess this meaningfully, it is important to understand how birds perceive their environment and to quantify aspects of the physical light environment, especially illuminance and photoperiod effects, on the functional development of the eye and vision. These gaps in our understanding of poultry responses to the light environment must be bridged before we can explore meaningfully the relationship between lighting in broiler chickens houses and poultry well being.

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