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Effect of Light Intensity on Production Parameters and Feeding Behavior of Broilers

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Effect of Light Intensity on Production Parameters and Feeding Behavior of Broilers.

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ABSTRACT

The purpose of this study was to determine, among the light intensities currently in use in the poultry industry, if broilers prefer to eat under a particular light intensity without affecting production performance. This project was performed in two parts. The first was focused on light intensity as it affects performance. A randomized complete block design (RCBD) was performed. Broilers, Cobb 500 (n = 1584) were housed in 3 commercial houses (121.9 x 12.2 m). In each house birds were randomized and placed in 72 pens of 121.9 x 121.9 cm (22 bird/pen, males and females). All the treatment groups were provided with 24h light (L) during the first week and then 18L:6Dark (D) and 20 lux from day 7 to 14. The 3 intensity treatments of 5 lux (lx), 10 lx and 20 lx (24 replications) with 18L:6D were started at day 14 and continued until 40 days of age.

The second experiment was designed to determine if birds showed a preference for light intensity while eating. A RCBD was performed with 3 different light intensities. Cobb 500 broilers (n= 180), were housed in 1 commercial house. They were placed in 6 pens. Each pen had 3 rooms with a specific light intensity and one feeder so the birds could choose under which intensity to eat after 14d of age. Feed disappearance for each feeder was collected and the lighting program was the same as in trial number one. Also a camera was set to record the feeding behavior of the birds (number of birds per treatment during one hour at a random time during the daylight period, before light turns off and one hour after light turns on).

In the first experiment there was no effect of light intensity on the production parameters. In the feed preference experiment there was a significant difference among the treatments ($p<0.0001$) in the total feed disappearance at the end (40 days) in which the 20 lx treatment showed the

highest value. The feeding preference trial showed that the broilers prefer to eat under the 20 lx light intensity ($p<0.05$) in all the three times during the day.

The results suggest that from a welfare perspective meat-type broiler chickens prefer to eat and drink under 20 lx rather than 5 lx which is the common commercial practice. Results suggest that a greater attention to light intensity, particularly with respect to feeder placement, may not only benefit production performance, but also bird welfare due to their preference for increased light intensity when feeding.

Key words: Photoperiod, light preference, welfare, chicken.

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I INTRODUCTION

The livestock sector has an increasing awareness of animal welfare and this has been especially important in the poultry industry. Although the production systems must follow standard guidelines regarding farm animal welfare stipulated by several organizations like the National Turkey Federation or National Chicken Council, several studies suggest that a relatively important consumer segment feels uncomfortable with those animal welfare levels (Stolz et al., 2011; De Jonge and Van Trijp, 2013a; De Jonge and Van Trijp, 2013b). Consumers have the perception that organic production or free range systems provide higher levels of animal welfare than conventional systems (Tuyttens et al., 2008) and also are recognized in certification programs (for example the Animal Welfare Approved certification) that provide a better standard for animal welfare. However, free range or organic meats are a viable alternative only for a small segment of consumers due to higher prices associated with these practices. In spite of the higher prices of these products, consumer dissatisfaction with the current meat supply chain has driven new initiatives from producers, governments and organizations for the development of new production and, management systems and guidelines to improve animal welfare (Veissier et al., 2008;Oosterkamp et al., 2011; Stolz et al., 2011). These market initiatives aim to get a balance between improving animal welfare while staying within an acceptable price range and profitability. It is very important that science-based welfare principles are used to obtain data for improving consumer perceptions of animal welfare in livestock farming (De Jonge, 2013). In addition, the need for efficient poultry welfare assessment and monitoring methods are necessary. The scientific community is making efforts to meet these demands (Müller et al, 2015; Shimmura et al., 2011).

The domestic chicken is the most common bird in the world, with a population around 19.9 billion (FAO, 2013). When considering animal welfare challenges and problems related to farming, the size of the poultry industry highlights the importance of studies that aim to understand and mitigate welfare problems related to poultry production.

With focus on poultry production and specifically in the meat-chicken sector, the study of de Jonge and Van Trijp (2013) found that consumer perception of welfare in broiler system practices listed outdoor space (access to natural light) as an important need followed by capping stocking density. On the other hand, transport duration and breed selection for growth rate came out as significant but less salient broiler system attributes regarding the perception of animal welfare.

Lighting is a key component in the poultry production; it is the most critical exogenous factor as it controls physiological and behavioral processes in the bird (Manser, 1996). Since the beginning of intensive poultry production light has been an important management tool to regulate poultry production, health and welfare. The first paper that assessed the improved production of poultry by using artificial lighting came from the University of Davis in 1917 (Dougherty, 1922). Although numerous studies have been conducted on the effects of lighting on the performance of poultry, in recent years more attention has been given to its effects on behavior and bird wellbeing.

Because of the importance of light from the consumers and producers points of view, as well as the physiology of the bird, this study was designed to focus on the effect of light intensity on the production performance and feeding preference behavior under different light intensities as a measure of broiler welfare.

II. CHAPTER I. LITERATURE REVIEW

A. ANIMAL WELFARE

The attention of the general public was first drawn to the welfare of animals kept under intensive husbandry conditions by the publication of Animal Machines (Harrison, 1964). Due to public response to this book in Britain, the Government formed the Brambell Committee whose final report (Command Paper 2836, 1965) stated that, "Welfare is a wide term that embraces both the physical and mental well-being of the animal. Any attempt to evaluate welfare, therefore, must take into account the scientific evidence available concerning the feelings of animals that can be derived from their structure and functions and also from their behavior." In addition, the definition animal welfare in terms of 5 freedoms was defined by the Farm Animal Welfare Council in 1979 as: 1) The freedom from hunger and thirst, 2) the freedom from discomfort by providing an appropriate environment including shelter and a comfortable resting area, 3) the freedom from pain, injury, and disease by prevention or rapid diagnosis and treatment, 4) the freedom to express normal behavior by providing sufficient space, proper facilities, and company of the animal's own kind, and 5) the freedom from fear and stress by ensuring conditions and treatment which avoid mental suffering. Hughes (1976) defined welfare as "A state of complete mental and physical health, where the animal is in harmony with its environment." Carpenter (1980) stated that "The welfare of managed animals relates to the degree to which they can adapt without suffering to the environments designated by man. So long as a species remains within the limits of the environmental range to which it can adapt, its well-being is assured."

.In order to establish some common ground, the simplest definition of animal well-being is: "Animal well-being is a condition of physical and psychological harmony between the organism and its surroundings" (Hurnik et al, 1985)

Moreover, Hurnik in 1990 indicated that all farm animals should have:

- Adequate air, water, and feed supply, according to their biological requirements.
- Safe housing and a sufficient amount of space to prevent injuries or atrophies and ensure normal growth.
- Appropriate level of environmental complexity to prevent harmful deprivation and boredom or aversive stimulation and fear.
- Regular daily supervision and effective health care to minimize undetected accidents, injuries, or illness and to initiate prompt assistance.
- Sensible handling in all stages of their life to avoid unnecessary suffering.

More recently, Sejian et al., (2011) defined animal welfare as the "the ability of an animal to cope physiologically, behaviorally, cognitively, and emotionally with its physiochemical and social life environment, including the animal's subjective experience of its condition". Therefore, animal welfare assessments can be based on physiological, physical, behavioral, and production-related measures. A combination of resource and animal based measures might be complementary in assessing animal welfare, and together provide the most valid assessment of welfare. It is critical that regulations and certification are expressed in terms of resource-based criteria related to farm and management characteristics (Temple et al., 2012),

Animal welfare is also a moral issue and what is considered acceptable and unacceptable in livestock farming differs among individuals, cultures and countries, and also changes over time (Ohl and Van der Staay, 2012). Van der Naald and Cameron (2011) found that consumer willingness to pay for welfare-enhanced meat products was positively related to the degree to which consumers believed that "humanely raised" standards improved the wellbeing of farm

animals. In addition to the moral component which makes it a difficult matter to define there is still lack of animal welfare knowledge in some regions of the world, for instance a recent study conducted in China by You et al (2014) indicates that from 6,006 effective questionnaires approximately two thirds of the respondents had never heard of 'animal welfare'.

Brake (2009) in his Animal welfare in a global perspective report indicates that there are worldwide variations in practices concerning farming and the keeping of animals and regarding wildlife. There is a positive trend of increasing attention for animal welfare issues around the globe. The interest in animal welfare can be driven by legislation through public (citizen) concern (countries in the EU are included in this category). It can also be driven by export considerations affecting animal welfare through health and food safety standards (Latin America and exporting countries in South East Asia are examples). In some cases, domestic (and foreign) consumers are forcing the production chain to change (North America). Countries in Africa and in Asia may lack these three driving forces.

Various countries view the need to improve animal welfare very differently, and because the driving forces for change also differ per country and region, there is a need to create internationally accepted standards (Brake, 2009).

As we can see there are difficulties in defining welfare, but one common criterion is the non-acceptance of cruelty (Verbeke and Viaene, 2000).. However, the welfare problems in intensive animal production systems lie in a grey area between extremes. This is where the arguments have been and will continue and therefore more research must be done.

Finally, there must be a balance between improving animal welfare production systems and the economic feasibility of proposed changes. In fact the study made by Gocsik et al (2013) shows

that the feasibility and sustainability of systems with improved animal welfare predominantly depends on the economic returns that farmers receive.

B. BROILER WELFARE

Predominant broiler production systems are associated with various welfare problems according to some animal scientists (Bessei, 2006; Bokkers et al., 2011; Robins and Phillips, 2011; Dinev, 2012), as well as consumers (Verbeke and Viaene, 2000).

The welfare problems in broiler production are pointed out by de Jonge and Van Trijp (2013) and include:

- Rapid growth rates affect broiler welfare because are associated with physiological problems in birds related to cardiovascular disease and leg disorders (Bessei, 2006; Robins and Phillips, 2011; Dinev, 2012).
- Stocking density exceeding 16 birds/m^2 leads to compression of birds, which reduce opportunities for behavioral expression (Bokkers et al; 2011) .
- The light program is another factor that could affect animal welfare. Since 2010, the EU has required at least one uninterrupted period of darkness for at least 4 h. However, it has been argued that at least 8 h of near-darkness (less than 5 lx) is necessary to encourage a normal biological rhythm, where the day-night cycle is synchronized with the animals' circadian rhythm/biological clock (Bessei, 2006; Robins and Phillips, 2011). Bayram and Ozkan (2010), show that only one hour of darkness negatively influences bird welfare because it does not enable broilers to develop a biological rhythm, and negatively influences locomotor activity and that, in a natural day-night regimen (e.g., 16L:8D), the average activity level in the light phase is higher, which positively influences leg conditions. Outdoor access stimulates

locomotion, which results in better leg health. In addition, broilers with access to free range showed their natural patterns of behavior much more frequently compared with birds kept in the conventional system (Skomorucha et al., 2007) and greater bone strength in the tibia (Van de Weerd et al., 2009). However, there are also some risks (predation, parasites, reduced biosecurity) associated with outdoor use (Van de Weerd et al., 2009)

- Enrichment of the environment with perching materials, pecking objects, and straw bales allows birds to expand their behavioral repertoire (Bessei, 2006). Although Robins and Phillips (2011) conclude that "no studies have yet demonstrated that on a commercial scale environmental enrichment is of significant benefit to bird welfare".
- Transport of broilers to processing plants has been associated with risk of broiler welfare problems (Vecerek et al., 2006). The duration of transportation is one of the factors that influence bird welfare, where increased transport duration is associated with increased mortality of broilers (Vecerek et al., 2006). There are standards established in EU to decrease the welfare problems during transportation: maximum duration of transport, stocking density during transport, the application of a temperature measurement system, and ventilation specifications among others (Robins and Phillips, 2011).
- With respect to the slaughter stage, controlled atmosphere stunning systems have welfare-related advantages relative to electrical water-bath stunning (Von Holleben et al., 2012; Lines et al., 2012).

Even more factors that can impact broiler welfare were identified by Bessei (2006):

- Selection for fast early growth rate along with feeding and management procedures which support growth have led to various welfare problems (Bauer et al., 1996).: Metabolic

disorders causing mortality by the Sudden Death Syndrome (Gardiner et al., 1988) and ascites (Maxwell and Robertson; 1997).

- Decreased locomotor activity and extended time spent sitting or lying on poor quality litter produces skin lesions at the breast and the legs (Bessei, 1992).
- Management factors which slow down early growth alleviate many welfare problems. Since growth is a main economic factor, there are problems of acceptability of these measures in commercial broiler production facilities (Bessei, 2006).
- Stocking density impacts growth rate and leg problems acting through its influence on litter and air quality (Reiter and Bessei, 2000). High stocking density impedes heat transfer from the litter surface to the ventilated room (McLean et al.; 2001).
- Lighting programs with reduced photoperiods are considered essential for the stimulation of locomotor activity and the development of a diurnal rhythm in the birds but, extended dark periods reduces growth when applied in the first weeks of age (Zubair and Leeson, 1996).
- Environmental enrichments have shown only moderate effects on the behavior and physical conditions of broilers (Bessei, 2006).

The OIE (Article 7.10.3.) indicators to evaluate broiler welfare include:

- Daily mortality, culling and morbidity checks, with weekly and cumulative mortality, culling and morbidity rates within expected ranges.
- Gait scoring should be monitored as, broilers that are lame or have gait abnormalities may have difficulty reaching the food and water, may be trampled by other broilers, and may experience pain. Musculoskeletal problems have many causes, including genetics, nutrition, sanitation, lighting, litter quality and other environmental and management factors.

- Dermatitis, affects skin surfaces that have prolonged contact with wet litter or other wet flooring surfaces.
- Evaluation of the feather condition of broilers provides useful information about welfare. Plumage dirtiness is correlated with contact dermatitis and lameness for individual birds or may be associated with the environment and production systems.
- Incidence of diseases, metabolic disorders and parasitic infestations
- Behavior evaluation: fear behavior, spatial distribution, panting, dust bathing, feeding, drinking, foraging and feather pecking and cannibalism
- Water and feed consumption, monitoring daily water consumption is a useful tool to indicate disease and other welfare conditions.
- Performance evaluation: growth rate, feed conversion and livability.
- Injuries include those due to other broilers (scratches, feather loss or wounding due to feather pecking and cannibalism) and those due to environmental conditions, such as skin lesions.
- Vocalization. It can indicate emotional states, both positive and negative.

In conclusion the welfare problems of broilers could be caused by factors which enable fast early growth, such as genetic background and extended lighting programs. Fast growing lines under continuous light programs decrease their locomotor activity and increase the time spent sitting particularly as birds age. Low locomotor activity in combination with high early growth rate causes development problems in leg bones and cartilages, which result in deformation of leg bones and gait anomalies. Extended periods of time sitting on wet litter lead to skin lesions on the breast and legs, and contribute to deterioration of bird welfare. It has been indicated that measures which reduce early growth rate generally improve the welfare of broilers (Bessei, 2006). The use of slow growing broilers as an alternative to reducing growth rate in fast growing

broilers has been shown to be more efficient in reducing leg weakness and metabolic diseases Fanatico et al., 2006). Stocking density influences welfare criteria mainly through litter and air quality, and its negative effects can be reduced by adequate management procedures. Moisture and temperature of the litter increase with age of the broiler flock and with increasing stocking density. This leads to thermal discomfort of the animals at the end of the grow-out period. Several characteristics of farm management systems and practices have implications to farm animal welfare, and adjustments to practices that are applied in broiler production may provide potential for improving animal welfare standards and consumer perceptions of broiler welfare. Among the many factors mentioned that have impact on broiler welfare, lighting is one of the most important and the purpose of this study is to evaluate the effect of light intensity on broiler welfare.

C. LIGHTING IN BROILER PRODUCTION

Lighting is the most powerful exogenous factor in control of many physiological and behavioral processes (Olanrewaju et al; 2006). It is integral to sight, including both visual acuity and color discrimination (Manser, 1996). According to Olanrewaju et al (2006) light allows the bird to establish rhythmicity and synchronize many essential functions, including body temperature and various metabolic steps that facilitate feeding and digestion. Also light stimulates secretory patterns of several hormones that are involve in the control of growth, maturation, and reproduction. 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, 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).

Light as an environmental factor that 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 increase in activity can stimulate bone development, thereby improving 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 (Olanrewaju et al., 2006).

When considering lighting programs as a management tool, both light intensity and duration are factors that are normally considered. In the United States, a typical broiler lighting program in a solid wall house might consist of a light intensity of at least 20 lx provided continuously from 1 to 7 d post-hatch. After 7d a restriction in both intensity (3 to 5 lx) and duration (16 to 20 hours of light) is usually implemented (Cobb Broiler Management Guide. 2012).

D. LIGHTING IMPACTS ON BROILER WELFARE

Genetic selection has resulted in high yield broilers with fast growth rate and better feed conversion. This genetic potential should be accomplished with good environment and nutrition, in order to avoid health and welfare issues like skeletal and circulatory problems associated with rapid growth rate. Therefore, the quality of environmental management could affect the production parameters and welfare status by improving or declining both. Light quality, levels, and duration are all extremely important to broilers (Olanrewaju et al., 2011). Light is one of the major environmental factors for poultry production that influences growth development and

physiological functioning (Olanrewaju et al., 2009). One of the major functions of lighting programs is to influence growth rate of broilers (Olanrewaju et al., 2011). Lighting has an important impact on the incidence of diseases attributed to fast growth allowing birds to achieve physiological maturity prior to maximal rate of muscle mass accretion. For example, decreased photoperiods are reported to diminish 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). Intermittent lighting programs can reduce lameness and circulatory problems in broilers and roasters (Kristensen et al., 2004). Behavioral evaluations have shown that broilers exposed to intermittent lighting are more active during the light periods (Simmons, 1982; Simmons and Haye, 1985).

E. LIGHT INTENSITY ON BROILER PRODUCTION AND WELFARE.

Light intensity is synonymous with illuminance and light level. It describes the quantity of light falling on a unit area and is measured with a light meter (or lux-meter) which is used to produce and read the photometric unit “lux” (lx) (Lewis and Morris, 2006).

In broiler production light intensity is often kept low (generally 5 lx) to inhibit bird activity and increase feed efficiency, as well to save energy (Appleby et al, 1992; Prescott et al., 2003). However, poultry have large eyes and excellent color vision (Nuboer, 1993) which suggests that they will have better quality vision and may have better welfare in more brightly lit environments.

Broiler behavior is strongly affected by light intensity. Brighter light will increase activity, while lower light intensity is effective in controlling aggressive behavior that can lead to cannibalism

(especially true in layer hens) (Kjaer and Vestergaard, 1999). However literature shows conflicting evidence about the light intensity effects on chicken activity.

Increased activity in brighter (6 to 12 lx) vs darker (0.5 lx) areas was reported by Newberry et al (1985). Another study suggested that as light intensity increased activity increased but decreased with each incremental increase in age (Newberry et al, 1986). In addition, low intensities have been associated with reduced walking and a standing and decrease of feather pecking and cannibalism (Buyse et al., 1996).

Blatchford et al (2012) indicate because broilers are commonly raised 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 has indicated that 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).

Relatively few studies of light intensity have shown significant effects on broiler production. In general, light intensity ranging from 1 to 150 lx has been found to have no effect on body weight, feed consumption, or feed conversion (Skoglund and Palmer, 1962; Newberry et al., 1988; Kristensen et al., 2006; Lien et al., 2007; Blatchford et al., 2009). When significant effects have been found, they have generally been deleterious effects of low rather than high light intensity on poultry production and welfare. Negative effects have included reduced carcass and tender yield, decreased early uniformity, increased incidence of leg disorders and ocular defects, abnormal behavioral expression, and increased fearfulness in birds (Hughes and Black, 1974; Newberry et al., 1988; Lien et al., 2007; Blatchford et al., 2009; Alvino et al., 2009). Dim light was found to

induce altered retina (peripheral darkened areas and non-pigmented white bands), choroiditis, lens damage, inflammation, and increased eye size and weight (Harrison et al., 1968; Jenkins et al., 1979; Siopes et al., 1984; Thompson and Forbes, 1999; Blatchford et al., 2009). Skeletal health was improved by stimulating activity at higher light intensity, but without consistent effects (Newberry et al., 1986, 1988; Blatchford et al., 2009). Dim light has increased leg and wing yield as a percentage of live weight (Downs et al., 2006; Lien et al., 2008).

Bright light has been suggested to improve welfare, because broilers have shown more pronounced behavioral rhythms and comfort behaviors under brighter light (Alvino et al., 2009). This is complemented with studies that show that broilers are more active when reared with high light intensity (180–200 lx) rather than low intensity (5–6 lx) (Newberry et al., 1988; Blatchford et al., 2009). In addition, the photoperiod is the dominant trigger of diurnal rhythms, but changes in intensity between light and dark appear to affect the strength of that trigger, with higher contrasts entraining more distinct rhythms (Daan and Aschoff, 2001). Therefore, activity rhythms are affected by contrasts in intensity (Blatchford et al., 2012).

In terms of broiler preference studies, Berk (1995) provided birds the chance to choose among several lighting intensities, he showed that broilers exhibited preference for light intensity by 6 wk of age. This study found that broilers (1 to 28 d of age) generally preferred brighter light (20 lx). Newberry et al., (1985) showed that when given a choice, broilers prefer to be in higher intensity light (12 lx) when they are performing active behaviors but in dimmer areas (0.5 lx) when resting.

Due to the importance of light intensity, various jurisdictions have established regulations to set standards. The European Union guideline requires the use of at least 20 lx of light intensity for

broiler production after the initial brooding phase (Council of the European Communities, 2007). Food Marketing Institute and the National Council of Chain Restaurants in 2003 and National Chicken Council in 2005 have restricted the use of photoperiods greater than 20 h and intensities of less than 20 lx.

Deep et al., (2010) concluded that, despite several publications regarding the negative effects on broiler production and welfare, the common practice and recommendation in the industry is still to use very dim lighting (less than 5 lx). Most management guides recommend a reduction in intensity after the early brooding period, but there is a debate about the appropriate level that should be used. There is the perception that very low light intensities improve feed efficiency, reduce mortality due to sudden death syndrome, and reduce carcass damage because of reduced activity (Downs et al., 2006). However, these advantages have not been confirmed by scientific investigation and in some cases are contrary to published data. Higher light intensity has been shown to increase bird activity and aggressive behavior (Hester et al., 1987; Newberry et al., 1988; Kjaer and Vestergaard, 1999), but a specific negative effect of higher light intensity within the range of 10 to 50 lx has, which is commercially applicable, has not been scientifically demonstrated in meat-type chickens (Deep et al., 2010).

F. DEFINITION AND CHARACTERISTICS OF LIGHT

It is important to understand what is light and why it is so important to birds. Light waves and other types of energy that radiate from where they are produced are called electromagnetic radiation. All the electromagnetic radiations make the electromagnetic spectrum (EM).

A wavelength is the distance between two consecutive peaks of a wave. This distance is given in meters or fractions of meters. Frequency is the number of waves that form in a given length of

time and it is usually measured as the number of wave cycles per second, or hertz (Hz). Electromagnetic radiation spans an enormous range of wavelengths and frequencies. This range is known as the electromagnetic spectrum. The spectrum is generally divided into seven regions, in order of decreasing wavelength and increasing energy and frequency the types of EM are:

- Radio waves
- Microwaves
- Infrared
- Visible light
- Ultraviolet
- X rays
- Gamma rays

Visible light is found in the middle of the EM spectrum, between infrared and ultraviolet. It has frequencies of about 400 Tera-hertz (THz) to 800 THz and wavelengths of about 740 nm to 380 nm, therefore visible light is defined as the wavelengths that are visible to most human eyes. The brain interprets the various wavelengths of light as different colors for example; red has the longest wavelength, and violet the shortest (Lamb, 1995).

G. THE IMPORTANCE OF LIGHT TO POULTRY

Physiological responses of poultry to light

The basic physiological effects of light are: facilitate sight (feed search), initiate and regulate hormone release (metabolic regulation, fat and muscle deposition), behavior and reproduction. One of the most visible physiological effects of light on growing poultry is the effect of day length on the onset of sexual maturity (Wilson and Cunningham, 1980).

In addition to the physiological effects of photoperiod length, light intensity can also affect poultry health and behavior (Deep et al., 2010).

Light management in broiler production

According to both the Cobb Broiler Management Guide (2012) and the Ross Broiler Management Handbook (2014) lighting programs are a key factor for good broiler performance and flock welfare.

Lighting programs are typically designed with changes occurring at predetermined ages and tend to vary according to the final target market weight of the broilers. Both manuals indicate that lighting programs should include 6 hours of continuous darkness as that will improve the development of the immune system.

The intensity and length of the photoperiod alters broiler activity. It is recommended that to ensure adequate feed and water intake 24 hours of light should be provided on the first day of placement and 25 lx in the darkest part of the house, as measured at chick height, be used during brooding (1 to 7 days of age) to encourage early weight gains with 23 hours of light. After 7 days of age, or preferably at 160 grams body weight, light intensities should be reduced gradually to 5-10 lx and 4 to 8 hours of darkness. This helps to prevent excessive growth between 7 and 21 days in order to reduce mortality due to ascites, sudden death, leg problems and spiking mortality and improve the welfare of the birds due a more normal biological rhythm including rest (Bessei, 2006).

The length of the dark period should be increased in steps and not in gradual hourly increases It is recommended that a minimum 4 hours of darkness should be provided from 7 days of age. Failure to do this will result in: abnormal feeding and drinking behaviors due to sleep

deprivation, suboptimal biological performance and reduced bird welfare (Ross Broiler Management Handbook, 2014).

When lighting programs for broilers are subjected to local legislation then the actual amount of darkness given must comply with local legislation. Just prior to processing giving an increased amount of light (for example, increasing to 23 hours of light 3 days before depletion) can help with feed withdrawal (by stabilizing feed intake patterns) and catching (by helping keep birds calm) but can have a negative impact on FCR and may not be in line with legislation in some areas (Ross Broiler Management Handbook, 2014).

Avian vision

The chicken (Gallus gallus) possesses seven photoreceptor cell types including one rod and six cones (Hart, 2001). They have tetrachromatic color vision mediated by four types of single cone which are maximally responsive to violet, blue, green and red light (Bowmaker et al., 1977). Double cones, in contrast, consist of pairs of closely apposed principal and accessory members which act as a single functional unit and are thought to mediate luminance detection that is used for motion perception (Maier and Bowmaker., 1993; Vorobyev and Osorio., 1988; Campenhausen and Kirschfeld, 1998). Placental mammals lack double cones and therefore use a single set of cones for both functional purposes (Osorio and Vorobyev, 2005).

The cones of modern birds have oil droplets that reside at the junction between the inner and outer segments and act as microlenses and long-pass spectral filters, focusing incoming light onto the photosensitive outer segment and improving color discrimination (Hart and Vorobyev, 2005). The majority of placental mammals possess only two types of cones, sensitive to short- and long-wavelength light (Vorobyev , 2003; Hunt et al., 2009). In addition, placental mammals lack double cones and oil droplets (Walls, 1942). Given the remarkable adaptations of the avian cone system for improved color discrimination light intensity plays a fundamental role in the

welfare of avian species and could be thought that very low light intensity environment could affect it because chickens are not adapted for such dim light intensity.

Chickens detect light not only through the retinal cone receptors in the eyes, but also via extra retinal photoreceptors in the pineal gland and the septal-hypothalamic area (Foster, R., and Soni, B., 1998).

Anatomical features of the avian eye

The avian eye has three characteristic shapes:

a) Flat, representing the majority of birds (*Gallus gallus*).

b) Globular, common to most Falconiformes.

c) Tubular, found in most owls (Strigiformes) and some eagles (Accipitridae).

The major structure of refraction in the avian eye is the cornea. Refraction occurs when light passes from one medium to a different one. The greatest change in the index of refraction occurs as light passes from the air through the eye. The lens, though playing a role in refraction, serves mainly as an adjustment during accommodation. Accommodation is the alteration of the refractive apparatus to maintain focus as the distance to an object changes. In birds the cornea generally plays the primary role in accommodation with the muscular ring around the lens also playing a secondary role in accommodation (Blackwell, 2002).

Retinal Organization

Because of its cellular organization, many of the complex functions of the avian visual system are accomplished in the retina. The retina first senses light, integrates the information, and passes the information onto the brain in the form of nerve impulses (Blackwell, 2002).

Other structures of the eye serve only to present the image to the retina. Also, as in most animals**,** the avian retina is duplex in nature, containing both rods (responsible for dim light or scotopic

vision) and cones (responsible for acute, bright light or photopic vision). The cones also serve to mediate color vision. The outer segments of the rods and cones contain the visual pigments, photosensitive material responsible for the absorption of light (Dartnall, 1962; Sillman, 1973). For an animal to have the ability to distinguish wavelengths irrespective of brightness, it must have a minimum of two separate classes of photoreceptor with different, but overlapping spectral sensitivities (Bowmaker 1987). Thus, most diurnal birds have retinas that are dominated by cones, with the rods being few in number and located primarily in the periphery (Blackwell, 2002).

In addition to single cones, the avian retina also possesses double cones (described in all classes of vertebrates, except placental mammals**).** For example, the retinae of most diurnal birds are represented by a single class of rods, a single class of longwave-sensitive double cones, and four classes of single cone (Sillman 1973). Also, each of the cone classes is associated with a particular type of oil droplet, situated at the distal end of the inner segments of cone photoreceptors (Goldsmith et al. 1984, Hart et al. 1998). Because cones are oriented such that their outer segments are farthest from incoming light, the light reaching the photosensitive outer segment of the retina will have to pass through the oil droplet (Bowmaker 1987). Most oil droplets contain carotenoid pigments (Wald and Zussman 1937, Goldsmith et al. 1984), which act as filters, removing some wavelengths and narrowing the absorption spectra of the pigments. This reduces the response overlap between pigments and increases the number of colors that a bird can discern (Bowmaker 1977; Chen et al. 1984; Bowmaker 1987; Partridge 1989). The spectral sensitivity of a cone photoreceptor is determined by both the spectral transmission of the oil droplet, lens and cornea, and the spectral absorbance of the visual pigment (Hart et 21.1998). Studies of the avian retina suggest that birds can distinguish colors ranging from the ultraviolet

(325-400nm; Bennett and Cuthill 1994) to the red (>700 nm; Huth and Burkhardt 1972, Bowmaker 1987, Bennett and Cuthill 1994). Hart et al. (1998, 2000) noted that a physiological dichotomy in short-wavelength photoreception might exist and be dependent upon phylogeny. For example, in addition to cone visual pigments maximally sensitive in the long-wave, mediumwave, and short-wave regions of the human-visible spectrum, avian retinae contain single cones with a visual pigment maximally sensitive to either violet or ultraviolet (Jane and Bowmaker, 1988; Hart et al. 1998). Human color vision is based on three color channels, each originating at one of three different types of photoreceptor. Therefore, three primary color sensations (blue/green/red) are evident, each resulting from stimulation of only one color channel. Secondary spectral colors in human color vision are mixtures of two neighboring primary colors (i.e., two of three receptors are stimulated) producing yellow (red and green) and cyan (blue and green) (Finger and Burkhardt, 1994). Birds, however, are considered tetrachromatic. In tetrachromatic vision, four primary colors should be expected: ultraviolet, blue, green and red. Also three spectrally neighbored mixed colors are possible: UV-blue, blue-green and green-red. Further there are three combinations of three of four color channels in birds is suspected to produce a new class of second –order mixed colors, ternary colors: UV-green-red, UV-blue-green, UV-blue-red and blue-green-red (Blackwell, 2002).

Perception

Birds respond directly to the number of photons striking photoreceptors (Endler 1990, Endler and Thery 1996). Thus, the perceived brightness of a light or reflected light is dependent upon photon density striking photoreceptors and (Endler, 1990):

1) Light reflectance and transmission to the eye of the animal.

2) Light transmission, refraction, and photoreception within the eye (species-specific).

3) Species-specific neural processes in the retina and brain that lead to the perception of light (Endler, 1990).

Avian species vary markedly in eye structure and physiology. Specific adaptations to maintaining focus, fixing upon an image, light intensity, and wavelength perception serve to distinguish the niche occupied by each species (Blackwell, 2002).

Reception

- Retinal reception:

  Rod and cone photoreceptors act in visual perception. Also retinal ganglion cells with melanopsin photoreceptor have light reception and form part of the diurnal cycle (Hart N.S., 2001).

- Extra-retinal reception (Foster, R., and Soni, B., 1998):

  The pineal gland with photoreceptors (sensitive to light intensity above 4 lux and its function is as a circadian clock (daily behavior cycles).

  The hypothalamic and septal regions have four proposed deep brain encephalic photoreceptor (DPB) types that and regulate sexual hormone production and metabolism. Red light wavelength around 650 nm penetrates the skull and brain (hypothalamus) four to 50 times more efficiently than blue, green and yellow-orange light, however has significantly less energy.

Magnetic perception

The relation between magnetic orientation and light will be discussed in this section. Beason and Semm (1991) indicated that birds have three magnetic receptor systems:

- A light dependent, wavelength sensitive system that appears to serve the magnetic compass.

- A magnetite based system that appears to provide positional information such as a map.
- A light dependent system in the Pineal Gland that influences circadian and perhaps circannual rhythms.

The receptor for the avian magnetic compass appears to require light and be sensitive to the color or wavelength of that light, but the responses to the wavelength of light do not appear to be consistent among species (Beason, 2003). Blue light has no effect on orientation and red causes disorientation in all species tested. However, the effects of intermediate wavelengths depend upon the species being tested; some are disoriented, some have a change in orientation, and some are unaffected. These differences might indicate differences in some aspect of the receptor system found among different avian species (Wiltschko and Wiltschko 1995, 1998; Wiltschko et al. 1993). The magnetite based receptor is associated with the ophthalmic branch of the Trigeminal nerve and it is much more sensitive to changes in intensity of the magnetic field than the light dependent system (Semm and Beason, 1990).

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III. CHAPTER II

A. Effect of light intensity on production parameters of broilers raised under commercial conditions

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B. ABSTRACT

Currently an important topic of discussion is light intensity and its effect on broiler welfare. A preliminary study was designated to evaluate the effect of different light intensities on broiler performance. A randomized complete block design (RCBD) with 3 treatments of 3 different light intensities of 5 lx, 10 lx and 20 lx was performed. Broilers Cobb 500 (n =1584) were housed in 3 commercial houses (houses are 122 m x 12.2 m and feeders, drinkers, ventilation and heating system are the same among them). In each commercial house birds were randomized and placed in 24 pens per house (72 totals) having a size of 121.9 x 121.9 cm (22 bird/pen, males and females). All the treatment groups were provided with 24L during the first week followed by 18L:6D and 20 lx from day 7 to 14. The 3 intensity treatments of 5 lx, 10 lx and 20 lx (24 reps) with 18L:6D were started at day 14 and continued until 40 days of age. Feed and water were provided ad libitum. Relative humidity and temperature were recorded and adjusted to follow Cobb's broiler manual recommendations. At 0d, 14d, and 40d all birds and feed were weighed.

At the end of the experiment, there was no effect of light intensity on feed intake, weight and feed conversion indicating no effect of various light intensities (5, 10 and 20 lx).

C. INTRODUCTION

Light is one of the major environmental factors that influence growth, development and physiological functioning in poultry production. One of the major functions of intensity in the lighting programs is to influence growth rate, feed intake and feed conversion of broilers.

A common practice in broiler production is the use of 20 lx or more the first 7 days during the brooding period followed by a decrease to 2-5 lx until market weight is attained. This practice has been used mainly to improve feed conversion (Downs et al., 2006).

Light intensity has been studied in the past, but relatively few studies have shown significant effects on broiler production. In general, light intensity ranging from 1 to 150 lx has not been found to affect body weight, feed consumption, and feed conversion (Skoglund and Palmer, 1962; Newberry et al., 1988; Kristensen et al., 2006; Lien et al., 2007; Blatchford et al., 2009).

Nonetheless an industry doctrine that has prevailed assumes that lower intensities improve feed conversion (FC) because of a reduction in activity (Downs et al., 2006), when in fact studies have not found significant effect on FC (Buyse et al., 1996; Charles et al, 1992; Lien et al. 2008).

The majority of the research done on the effect of light intensity on broiler live weight has found a significant increase when provided low light intensity (2 to 5 lux) when compared to higher intensities (Mckee et al., 2009; Charles et al, 1992; Olanrewaju et al, 2006; Downs et al, 2006).

A recent study by Ahmad *et al*. (2011) reported that light intensity ranging from 5lux to 40 lux had a non-significant effect on weight gain in broilers.

As mentioned above different scientists explored contradictory results regarding the effects of light intensity on production performance and the vast majority has not been done under commercial condition. The present study was conducted to determine the impact of three

different light intensities on production performance of broiler chickens under commercial conditions.

D. MATERIAL AND METHODS

Research site

The trial was conducted at the University of Arkansas Applied Broiler Research Farm at Fayetteville, Arkansas. The broiler farm comprised four earth-floored tunnel ventilated houses with cool cells to raise approximately 20,500 birds to about 43 to 45 d of age at a stocking density of 13.7 bird/m2. The houses were constructed in 1990 and had subsequently undergone many physical and structural improvements. The internal layout of each house comprised two automated feed lines running the length of the building and four parallel nipple water lines on either side of each feed lines. Prior to the first flock in this study, litter was removed, houses washed with chlorinated water, and a mixture of 50% rice hulls and pine shavings were provided to a depth of about 15 cm for new bedding. In subsequent flocks birds were raised on the same litter, as is widely practiced in the United States, but the surface layer, comprising any caked material, was removed (decaking). The feeding regime consisted of 5 rations: pre-starter from 0 to 7 days of age), starter (from 7 to 14 days of age), grower (from 15 to 28 days of age), first withdrawal (from 29 to 35 days of age), and second withdrawal feeds (from 36 until market weight). For this study 3 houses were used with a total of 72 pens (24 pens / house). Nutrition and management were based upon the Cobbs 500 nutrition and management guide.
Cobbs-500 broilers were housed in 3 commercial houses and placed in 72 pens of 121.9 x 121.9 cm (22 bird/pen, males and females) a total of 1584 birds. The pens were situated through the center of the houses, each pen had one hanging feeder, and water was provided by water lines with nipples (5 nipples per pen).

The housing lighting program consisted of 24 hours of light and an intensity of 60 lx the first 7 days of age. From 7 to 14 days, 18 hours of light and 6 of darkness with 20 lx were utilized. After 14 days of age the same photoperiod was used, however light intensity was dropped to 5 lux.

For the purpose of the trial, between 14 to 39 days of age, three light intensities were evaluated: 5 lx (control), 10 lx and 20 lx. Incandescent lightbulbs of 25 watts were the light sources utilized and located above each pen. This range of light intensity was studied due to its practical application in the industry. To measure light intensity a Luxometer – Extech Easyview® series EA31 was used.

Lux

Lux (lx) is a unit of illuminance which is a measure of how luminous flux is spread over a given area. Luminous flux, measured in Lumens (lm), is a measure of the total "amount" of visible light present and the illuminance (in lx) as a measure of the intensity of illumination on a surface in other words 1 lx equal 1 lm/m2.

According to Presctott and Wathes (1999) due to the difference already discussed in vision capacity between humans and birds, instead of lux, a more accurate term called clux (chicken lux) should be used. It retains the original meaning of a luminance flux incident on a given area implicit in the lux unit and accounts for the spectral sensitivity of the fowl, but which is still clearly differentiated. While peak lux can be assessed at any wavelength, the International Commission on Illumination (CIE) standard for measuring light intensity is set at the peak human response of 550–560 nm. The implication of a spectral sensitivity that is broader than that of a human is to increase the perceived luminosity of any light source, because luminosity is a measure of the total summed response of all of the cone species (Nuboer, 1986). Prescott and

Wathes (1999) findings showed a broader sensitivity than either the CIE curve or Wortel et al. data (1987). Importantly this means that the perceived intensity of artificial light to the fowl in photopic vision (is the vision of the eye under good luminance level conditions which allows color vision) will be greater than for a human. Chickens have four photopic (color) spectral peaks, therefore additional calculations utilizing the four poultry-specific peaks are required to measure clux units. Depending on the light source and peak spectrum, clux can be up to 50% or higher in light intensity than lux. Understanding the difference between lux and clux provides a more accurate selection of light bulbs for the producer and allows them to recognize the limitations of traditional light meters. While using a traditional light meter can be an indicator of light intensity in a house, there will always be a difference between lux and clux.

Experimental design

A randomize complete block design (RCBD) with houses as blocks, and three treatments of three different light intensities (5 lx as control, 10 lx and 20 lx) formed the experimental design. On the second day of age birds were weighed and put into the pens. When chicks reached 14 days of age, the light treatments started. Birds and feed were weighed at 2, 14 and 39 days of age. Treatment effects were evaluated between 14 to 39 days of age. Parameters measured were: feed conversion, bird live weight and feed intake.

Statistical analysis

All data were analyzed using JMP Pro 11.2.0 - SAS Institute Inc, 2013. Data were analyzed by ANOVA and when the effects were significant, means were separated by the LSD test at a significant p-value ($p < 0.05$). Analysis was performed in a RCBD with the houses as blocks and light intensity (5 lx, 10 lx and 20 lx) as treatments. Results are expressed as mean ± standard error.

E. RESULTS

The bird live weight at 39 days showed no significant difference among treatments with values of 2.320 ±0.03 kg, 2.354 ±0.03 kg and 2.328 ±0.03 kg for 5, 10 and 20 lx (table 1).

The total feed intake (kg) per bird at 39 days of age displayed no significant difference among treatments: 5 lx: 3.683±0.04 kg, 10 lx: 3.722±0.04 kg and 20 lx: 3.690±0.04 kg (table 1).

The Feed conversion (FC) showed no significant difference among treatments with values of: 5 lx: 1.592 ±0.002, 10 lx: 1.582 ±0.002 and 20 lx: 1.589 ±0.002 (table 1).

There were no significant differences among the treatment in any of the parameters evaluated.

F. DISCUSSION

The purpose of using dim light intensity in modern commercial poultry facilities is to optimize feed conversion, reduce energy utilization, improve production parameters and overall profitability. In this study there was not effect of light intensity (5 lx, 10 lx and 20 lx) on FC, feed intake (FI) and weight at 39 days of age. These results agree with the recent study by Olanrewaju et al (2016) who did not find a significant difference between 5 lx and 20 lx on the same parameters evaluated. In addition, previous studies found similar results. For example, Olanrewaju et al., (2011) demonstrated no effects of varying light intensity ranging from 0.2 to 25 lx on growth and production performances of broilers grown to heavy weights. Blatchford et al. (2009) found no difference in final body weight (BW) and gait score in broilers raised under 5, 50, and 200 lx. Deep et al., (2010) found no effect of light intensity (1 to 40 lx) on broiler growth and production performances. Ahmed et al (2011) reported a non-significant effect on weight gain in broilers when light intensities were compared from 5 to 40 lux. Lien et al. (2008) also reported that feed conversion was not affected by two diverse light intensity treatments 1.75 vs. 162 lx.

Similar results with no differences in broiler body weight gains were observed in older studies (Skoglund and Palmer 1962, Dorminey and Nakaue 1977). In addition, Newberry et al., (1986) who evaluated light intensities ranging from 0.1 to 100 lx could not find difference in FC. Again, Newberry et al., in 1988 did not find any difference in the FC between two treatments of 6 and 180 lx. Charles et al. (1992) reported no influence on feed conversion when exposed to light intensity of 6 lux versus 151 lx.

In contrast, there are other studies which found light intensity effects on production parameters. One of them is Kristensen et al. (2006) who observed an increase in body weight of broiler chickens due to light intensities ranging from 5.4 to 6.45 lx and decreased body weight when birds were kept under light intensity ranging from 107.6 to 124.7 lx. Cherry and Barwick (1962) and Charles et al. (1992) obtained similar results. Specifically the two research groups demonstrated improvement an in BW and FC with low light intensities (1 and 5 lx) in contrast to birds given much brighter light (100 and 150 lx) which is not similar to the present study. Very bright light (100 and 150 lx) might have stimulated the activity of broilers to the extent that they used more energy for maintenance instead of growth. Deep et al (2013) worked with industry use light intensities (0.5, 1, 5 and 10 lx) between 0-35 days old, demonstrated a quadratic response in body weight and feed conversion with a maximum at 5 lx and a positive linear response for feed intake and negative for foot pad lesions. Wathes et al. (1982) observed higher feed consumption at 3.2 lx relative to that occurring at 0.7, 16, or 50 lx. Similarly, Downs et al., (2006) reported an increased feed consumption and gained more body weight in broiler chickens provided 2.7 lux instead of 21.5 lux. A transitory decrease in feed consumption from 2 to 3 week was seen in broiler chickens subjected to 1.75 vs. 10.75 lx (Lien et al., 2007). Lien et al (2008) in a different study showed increased BW and feed intake (FI) with dim light (1 lx) in comparison to 150 lx.

Cherry and Barwick (1962) observed improved feed conversion as intensities were decreased from 107.5 to 1.75 lx. Charles et al. (1992) and McKee et al (2009) found a significant increase in bodyweight of broilers placed in low light intensity compared to those raised under higher levels of light intensity. Early reports indicate that broiler BW were consistently greater under intensities of 10 to 50 lx, relative to 60 to 120 lx, but continued BW increases under 5 lx to 1 lx were smaller and inconsistent (Barott and Pringle, 1951; Cherry and Barwick, 1962: Skoglund and Palmer, 1962; Wathes et al., 1982). Overall the studies that found differences in production parameters showed better performance under low light intensity- It is important to note, however, that the higher light intensities used in most of those studies were too high and not practical from a commercial point of view.

The current study (5, 10, 20 lx) did not find light intensity differences on feed intake which agree with several earlier studies with respect to feed consumption (Charles et al., 1992; Downs et al., 2006). Cherry and Barwick (1962) observed no effect of intensities from 1 to 100 lx on feed consumption, and Newberry et al. (1986;1988) in two different studies, reported no effect of intensities from 0.5 to 3o lx and of 6 and 180 lx on feed consumption.

Conversely, Wathes et al. (1982) observed greater feed consumption at 3 lx relative to that occurring at 0.7, 15, or 46.5 lx, and Newberry et al. (1986) observed an increase in feed consumption through 6 wk, but not 9 wk, in response to greater light intensities in the range of 1 to 100 lx.

There was not effect of light intensity on feed conversion, similar to other studies. Dorminey and Nakague (1977) observed no effect on FC in response to intensities of 2.5 lx vs 10 lx, Deaton et al., (1988) no difference in 2 vs 50.2 lx and Newberry et al (1988) 180 vs 6 lx.

A different result from Cherry and Barwick (1962) who observed improved feed conversion as intensities were decreased from 100 to 1 lx. Newberry et al. (1986) observed a decrease in feed conversion at 6 and 9 wk in response to lower intensities in the range of 1 to 100 lx.

It is generally accepted that changes in photoperiod result in changes in consumption and, subsequently, BW (Charles et al., 1992; Renden et al., 1993) and has also been assumed that lower intensities may improve feed conversion because of a reduction in activity (Newberry et al., 1986; Charles et al., 1992; Downs et al., 2006).

The small differences in treatment levels could influence the lack of effect of light intensity on overall live broilers production parameters. Since higher light intensity levels are viewed by the general public and animal welfare organizations as an improvement in broiler welfare, the findings of this research suggest strongly that it is possible to use a light intensity of 20 lx instead of the common practice of 5 lx without affecting bird performance and economic benefits, and improve the consumer opinion of broiler welfare.

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Table 1. Light intensity (5, 10 and 20 lux) effects on production parameters at 39 days old: Feed conversion (FC), weight (kg) and feed intake (kg).

	FC		Weight kg		Feed intake kg	
TRT	**Mean**	**SEM[1]**	**Mean**	**SEM**	**Mean**	**SEM**
5 lux	1.592	0.002	2.320	0.03	3.683	0.04
10 lux	1.584	0.002	2.354	0.03	3.722	0.04
20 lux	1.589	0.002	2.328	0.03	3.690	0.04
p value	0.963		0.3515		0.765	

[1]Standard error mean (pooled harmonic mean)

IV. CHAPTER III

A. Evaluate food choice by broilers under different light intensities in commercial production conditions.

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B. ABSTRACT

This experiment was designed to determine if broilers showed a preference for a particular light intensity while eating. A randomized complete block design (RCBD) was used with 3 light intensity treatments. Broilers (Cobb 500, n = 180) were housed in a commercial house. Broilers were placed in 6 pens. Each pen had sub-divisions or rooms. One sub-division served as the placement room (transit room) from which broilers had access to 3 equal-sized rooms, each with a specific light intensity: 5, 10 or 20 lx and a feeder placed directly under the light. Birds thereby could choose what light intensity they preferred when they ate. All treatments (trts) were provided with the same lighting program used in experiment 1 (Chapter II). Food disappearance in each of the 3 choice rooms was determined. A camera was set to record the feeding behavior of the birds (number of birds per trts during one hour at a random time during the photoperiod, one hour before light turned off and one hour after light turned on).

A significant difference in total feed disappearance was obtained among the three trts ($p=0.003$): 5 lux: 47.460 kg, 10 lx: 48.065 kg and 20 lx: 61.443 kg (the 20 lx trt was significantly different from the other two trts). The average number of birds recorded every 5 minutes per trt during each video session further indicated a preference for eating in the higher light intensities. The average number of birds for a random hour of the photoperiod was: 5 lx: 4 birds, 10 lx: 5 birds and 20 lx: 7 birds ($p<0.0001$); during one hour before light turned off: 5 lx: 3 birds, 10 lx: 5 birds and 20 lx: 6 birds. ($p=0.0004$) and for the hour after the light turned on: 5 lx: 4 birds, 10 lx: 5 birds and 20 lx: 8 birds. ($p<0.0001$). Results showed that broilers clearly preferred to eat under 20 lx than 5 lx which is the common industry practice. Therefore, greater attention to light intensity, particularly with respect to feeder placement may not only improve animal welfare but also benefit production performance.

C. INTRODUCTION

Lighting is a critical component of the environment of commercial broiler chicken and can influence health, productivity, and welfare of the confined broiler chickens (Olanrewaju, et al., 2006). Lighting has been shown to affect the physiology and behavior of domestic fowl (Buyse et al., 1996). The progenitors of broiler chickens lived in a natural environment, where the natural lighting was substantially different from the artificial lighting used inside commercial poultry facilities today. The natural light intensity on a sunny day may be as high as 100,000 lx (Thery, 2001) while the light intensity inside broiler houses commonly may be less than 5 lx at the bird level (Prescott and Wathes, 1999).

Bird preference has been assessed in response to exposure to different light intensities (Davis et al., 1999), light sources (Widowsky et al., 1992 and Vandenberg, et al., 2009), light colors (Prayitno, et al., 1997), and flickering frequencies (Widowski et al, 1996).

The preference test allows birds to choose among several environments that may differ in only one characteristic. Birds can thus indicate their behavioral response to a specific environmental condition by demonstrating whether they have any attraction or aversion to that characteristic (Duncan, 1992), hence providing an evaluation of their current environment. In this experiment broilers could provide data indicating their choice of light intensity by monitoring the intensity they selected for eating.

An underlying principle is that animals, including poultry, generally behave in a way that maximizes their fitness (Dawkins, 1990); thus, they preferentially choose features that will most likely satisfy their requirements, regardless of whether these are perceptible to humans (Mendes et al., 2013).

The objective of this study was to investigate the environmental preference made by broilers when given a choice of 3 light intensities (5 lx, 10 lx and 20 lx). Three choices of light intensities were selected ranging from 5 lx, the commercial standard and 20 lx, considered a better animal welfare level, as suggested by the European council directive (2007), American Humane Association and some other welfare audit organizations.

D. MATERIAL AND METHODS

Research site

The trial was conducted at the University of Arkansas Applied Broiler Research Farm at Savoy, Arkansas. The broiler farm comprised four earth-floored tunnel ventilated houses with cool cells to rear approximately 20,500 birds to about 43 to 45 d of age at final a stocking density of 13,7 bird/m2. The houses were constructed in 1990 and had subsequently undergone many physical and structural improvements. The internal layout of each house comprised two automated feed lines running the length of the building and four parallel nipple water lines, two lines on either side of each feed line. The litter consisted of a mixture of 50% rice hulls and pine shavings provided to a depth of about 15 cm for new bedding.

For this trial one commercial house with a population of 20.000 broilers was used and 6 experimental pens were placed inside. Nutrition and management were based upon the Cobb 500 Nutrition and Management Guide. Broilers (Cobb 500 birds) were housed in one commercial house and placed in 6 pens of 3,657 x 1,22 m (30 bird/pen, males and females) comprising a total of 180 birds.

The house lighting program consisted of 24 hours of light and an intensity of 30 lx the first 7 days of age. Between 7 to 14 days, 18 hours of light and 6 of darkness (LD18:6) with an intensity of 20 lx was initiated, and at 14 days of age, LD18:6 and a light intensity of 5 lux. At 14 days of age the light intensity trial started in the experimental pens (Fig. 1) with 5 lux, 10 lux

or 20 lx rooms where a single feeder was located in each of the three choice rooms. The three light intensities were randomly assigned so room preference was not involved. Cameras were utilized to evaluate choice of room and its light intensity during feeding. Incandescent lightbulbs were the light source for the experiment. To measure lux a Luxometer – Extech Easyview series EA31 was used.

Lux

Lux is a unit of illuminance which is a measure of how luminous flux is spread over a given area. Luminous flux (in Lumens) is a measure of the total "amount" of visible light present, and the illuminance as a measure of the intensity of illumination on a surface. One lux is 1 lumen/m2.

Experimental pens

In this trial 6 experimental pens of 3.657 x 1.219 m were used. Each pen consisted of 3 independent rooms of 0.72 m x 1.219 m and a transit area of 3.657 x 0.50 m (labeled 'transit pen' in Fig. 1) that allowed easy passage to any of the different light intensity trts. Each choice room was provided with a feeder and water line and a lamp with an incandescent light bulb as the light intensity treatment. Black plastic covered the walls of each room so that light from one room did not affect the light intensity of the adjacent room (figure 1).

Experimental design

A RCBD with big pens as blocks, with three treatments of three different light intensities (5 lx, 10 lx and 20 lx) was implemented. At the second day of age birds were weighed and placed randomly into one of the six pens. At 14 days of age the light treatments started and all 18 feeders were weighed. Thereafter feed was measured based upon what was added to each feeder as needed. Feed disappearance was calculated per treatment. Data for each of the 3 treatments were obtained between 14 to 39 days of age. GoPro™ cameras were set above each pen. They

were used in burst mode (one picture every 0.5 seconds) to record the number of birds per light treatment every 5 minutes during one hour after the lights turned on (1:00 am), before lights turned off (6:00 pm) and during a random hour during the day (not the first or the last hour).

Statistical analysis

All data were analyzed using JMP Pro 11.2.0 - SAS Institute Inc, 2013. Data were analyzed by ANOVA and when the effects were significant, means were separated by Least Significant Difference (LSD) test at a significant p-value < 0.05. For statistical analysis the big pens served as blocks and the three light intensities as treatments. Results are expressed as mean ± standard error.

E. RESULTS

Feed disappearance (FD)

From 14 to 39 days of age the three light intensity treatments were conducted and Feed disappearance (FD) for each trt over the 25 day period was calculated per room. A significant difference among the 3 trts was obtained (p value= 0.003) with 20 lx significantly higher than 10 lx and 5 lx. The total FD (see table 1) in kg for 5 lx was 47.460 ± 2.42 kg, 10 lx 48.065 ± 2.42 kg and 20 lx 61.443 ± 2.42 kg (n = 6/trt).

Bird Preference

Number of birds tabulated per light treatment during a random hour of the photoperiod

The GoPro™ camera was used to take two pictures every second (burst mode) during a random hour in the middle of the photoperiod (not the first or last hour). A GoPro™ camera was available for each of the six big pens. Then every five minutes within the hour the number of bird per treatment was recorded. The average number of birds per treatment every 5 minutes during a random hour in the day was used to compare the treatments. The results were for 5 lx 4 ± 0.682 bird/trt, 10 lx 5 ± 0.682 bird/trt and 20 lx 7 ± 0.682 bird/trt. There is a statistically

significant difference among the means (p=0.0125) where 20 lx presented significantly higher values than 5 lx.

Number of birds tabulated per light treatment one hour before the lights turned off

The same method used for determining which light trt was preferred during a random hour between 1hr after lights on and 1hr before lights off was used for determining the light intensity preferred during the hour before lights turned off. The results for 5 lx 3 ± 0.557 bird/trt, 10 lx 5 ± 0.557 bird/trt and 20 lx 6 ± 0.557 bird/trt. There was a significant difference among the means (p=0.0004) with 20 lx and 10 lx significantly higher than 5 lx.

Number of birds tabulated per light treatment one hour after the lights turned on

The same method was used for determining the number of birds/light trt occurred during one hour after the light turned on. The results for the 3 light trts were for 5 lx 4 ± 0.649 bird/trt, 10 lx 5 ± 0.649 bird/trt and 20 lx 8 ± 0.649 bird/trt. There was a significant difference among the means (p<0.0001) with 20 lx higher than 10 lx and 5 lx.

Average number of birds per time of the day every five minutes in the transit area.

The purpose of counting the number of bird in the common area (light intensity of 5 lx) is to determine if there is a difference in the number of birds that are not eating or closer to the feeder among a random hour, first hour and last hour of the photoperiod. The same method was used (counting bird in transit area every 5 minutes during one hour and then the average number was used to compare means). The average number of birds every 5 minutes in the lobby area in a random hour was 13 ± 0.630 birds, during one hour after the light turns on was 11 ± 0.607 birds and one hour before light turns off 15 ± 0.656 birds (table 5).

Average number of bird per treatment (5 lx, 10 lx and 20 lx)

Comparing the average number of birds every 5 minutes during one hour among the various light intensities gives an idea of the overall preference during the photoperiod. Under 5 lx 2 ± 0.35 bird/5 min, 10 lx 3 ± 0.35 bird/5 min and 20 lx 5 ± 0.35 birds/5 min. There is a significant difference among the means with a p value < 0.0001. The 20 lx light intensity treatment showed the highest number of birds, followed by the 10 lx treatment which was also higher than the 5 lx treatment. Overall birds preferred to eat and drink in the room that had a light intensity of 20 lx (table 6).

F. DISCUSSION

Studies have shown that lighting affects rhythms of feeding behavior (Weaver and Siegel, 1968; Savory, 1976; May and Lott, 1992), but the purpose of this trial was to determine if there is a preference for light intensity when eating. If there was no preference for light intensity, young chickens would be expected to distribute themselves randomly among the environments with feed and water available regardless of light intensity. In the present study, there was a preference by the chickens for eating/drinking with the higher light 20 lx intensity than either the 5 or 10 lx light intensities (tables 2, 3 and 4). This preference is not only supported by the greater number of birds in the 20 lx pen (table 6) but also the elevated feed consumption in the 20 lx pens (table 1). This is the first definitive demonstration that there is distinct preference by chickens for a higher light intensity, at least, for feeding and drinking. Buyse and colleagues (1996) concluded the literature on light intensity and chickens was “inconsistent”. Present data from this study strongly suggest that light intensity is a strong “driving force” for chicken distribution. There have been few consistent preference effects reported in choice studies in chickens (Senaratna et al., 2012; Senaratna et al., 2014). Meat type chickens showed little preference for environments

illuminated at 20 lx with white or red or green or blue light in a photoperiod of 20L: 4D (Senaratna et al, 2012). In contrast to the marked differences in food consumption in the present study (table 1), there was no consistent effect of intensity of red lighting (5, 10, 20 lx) on time spent eating by young chickens in the study of Senaratna et al., in 2014. In addition, the Mendes et al (2013) preference study showed that birds did not show any preference for white vs. yellow LED environments (light intensity 20 lx first week and 20 lx from second to sixth week).

It could be predicted that chickens would spend little time in the transit pen that allowed chickens to migrate to the feeders and waterers in pens A, B and C (figure 1) and, it was considered probable that the chickens would be observed close to the feeders and waterers. However, this was not seen. It was completely unexpected that young chickens seemed to congregate in the dimly lit transit pen (5 lx) (table 5). Thus, it is logical to conclude that chickens move away from the areas where they feed/drink to an area of low light intensity to rest. There appears to be a preference for eating at 20 lx and for resting at 5 lx. Davis and associates (1999) concluded that at six weeks of age, chicken"prefer to spend much of their time in a light environment of < 10 lx intensity" (Davis et al., 1999). The preference for a higher light intensity (20 lx) compared to dim light (5 lx) for feeding (tables 2, 3 and 4) parallels the results of earlier work when chickens were trained to peck to switch on lights, which they did when feeding (Savory and Duncan, 1982).

This present experiment agrees with Newberry et al (1988) who found that there was a significant light intensity x age interaction for feeding, with birds spending more time feeding in bright than dim light at 2, 5, 7, and 9 week and less time in the remaining weeks, and also with Newberry et al (1985) that when given a choice, broilers prefer to be in higher intensity light (12 lx) when they are performing active behaviors but in dimmer areas (0.5 lx) when resting which is

similar with the present study in which more birds were found in the 20 lx chamber (performing the active behavior of eating) while the majority was resting in the lobby under the lowest light intensity.

In the transit pen there were fewer birds during the hour before light turns off and after light turns on than during one hour in the middle of the day (table 5). This indicates that broilers are more actively eating during these hours than in the middle of the day when they are resting more. Comparing the number of birds per treatment, regardless of the time, indicates that broilers prefer to eat and drink under 20 lx rather than 10 lx and 5 lx, and also more under 10 lx than 5 lx. This result could be linked with some studies evaluating light intensity and behavior. For example Newberry et al (1985) found that when broilers were raised in pens containing areas of 12 and 0.5 lx intensity, they performed more of their active behaviors (e.g., moving, standing) in the brighter areas and more of their non-active behaviors (e.g., lying) in the dimmer areas. Similarly, broilers reared with light intensities that alternated between 100 and 5 lx were more active during the periods of high intensity lighting (Davis et al., 1999; Kristensen et al., 2006). Broilers raised under high (180 lx) intensity light were also found to be more active than broilers raised under low (6 lx) intensity light (Newberry et al., 1988).

The results from this trial contradict previous studies which indicate that feeding behavior is not affected by the different light intensities, (Weaver and Siegel, 1968; Charles et al., 1992; Downs et al., 2006; Kristensen et al., 2006) and that that feeding patterns are more influenced by day length rather than light intensity per se (Morris, 1968; Savory, 1976). This trial demonstrates the important relationship between light intensity and feeding behavior.

From an animal welfare point of view chickens may prefer to eat under the brightest light intensity due to a better spatial acuity which improve the visual perception of the feed plus a higher feeding activity stimulated by a brighter light intensity.

In addition, the finding that meat type chickens prefer to spend some of their time in a light environment with an intensity of 5 lx, which is contrary to current recommendations (European Commmission, 2007) that minimum light intensities for broilers should be increased to as much as 20 lx. The results from this trial suggest a distribution of ambient light intensity, to provide both 5 lx (away from feeders) and 20 lx (at or near feeders) environments, might benefit the welfare of broiler, although further work is needed to establish the optimal light environment.

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Table 1. Effect of the three light intensity treatments on the total feed disappearance (kg) at 39 days of age.

TRT	Total Feed disappearance kg	SEM[1]
20 lx	61.44[a]	2.42
10 lx	48.06[b]	2.42
5 lx	47.46[b]	2.42
p value	0.003	

Values (a, b) not connected by same letter are significantly different ($p<0.05$)
[1]SEM, standard error of the mean (pooled harmonic mean)

Table 2. Average number of birds per treatment every five minutes during one random hour (not the first of last) of the photoperiod.

Treatment	Mean	SEM[1]
20 lx	7.09[b]	0.668
10 lx	5.18[c]	0.668
5 lx	4.09[c]	0.668
Transit pen	13.63[a]	0.668
p value	< 0.0001	

Values (a, b, c) not connected by same letter are significantly different ($p<0.05$)
[1]SEM, standard error of the mean (pooled harmonic mean)

Table 3. Average number of birds per treatment every 5 minutes during one hour before the lights turned off.

	Before Lights off	
Treatment	**Mean**	**SEM[1]**
20 lx	6.66[b]	0.86
10 lx	5.09[b]	0.86
5 lx	3.18[c]	0.86
Transit Pen	15.07[a]	0.86
p value	< 0.0001	

Values (a, b, c) not connected by same letter are significantly different ($p<0.05$)
[1]SEM, standard error of the mean (pooled harmonic mean)

Table 4. Average number of birds per treatment every five minutes during one hour after the lights turned on for the day.

	After Light on	
Treatment	**Mean**	**SEM[1]**
20 lx	8.91[b]	0.9
10 lx	5.66[c]	0.9
5 lx	4.11[c]	0.9
Transit Pen	11.31[a]	0.9
p value	< 0.0001	

Values (a, b, c) not connected by same letter are significantly different ($p<0.05$)
[1]SEM, standard error of the mean (pooled harmonic mean)

Table 5. Average number of birds per time of the day every five minutes in the transit pen.

	Transit pen	
Treatment	**Mean**	**SEM**
Middle of photoperiod	13.63[a]	0.63
Before light off	15.07[a]	0.66
After light on	11.31[b]	0.61
p value	0.0007	

Values (a, b) not connected by same letter are significantly different ($p<0.05$)
[1]SEM, standard error of the mean (pooled harmonic mean)

Table 6. Average number of bird per treatment (5 lx, 10 lx and 20 lx).

TRT	Number of birds	SEM[1]
20 lx	7.14[a]	0.34
10 lx	5.29[b]	0.34
5 lx	3.77[c]	0.34
p value	< 0.0001	

Values (a, b, c,) not connected by same letter are significantly different ($p<0.05$)
[1]SEM, standard error of the mean (pooled harmonic mean).

Figure 1. Preference pen for trial 2

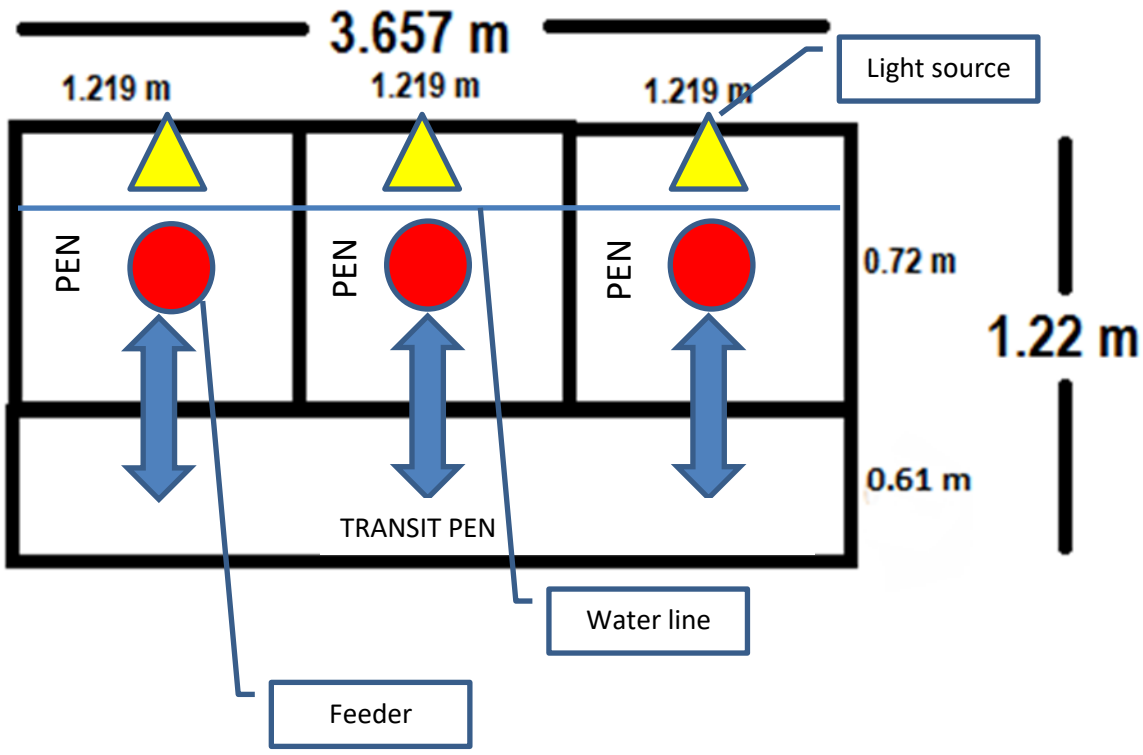


Figure 2. Average number of birds per treatment every five minutes during one random hour (not first of last) of the photoperiod (error bar is constructed using on standard error from the mean (pooled harmonic mean).

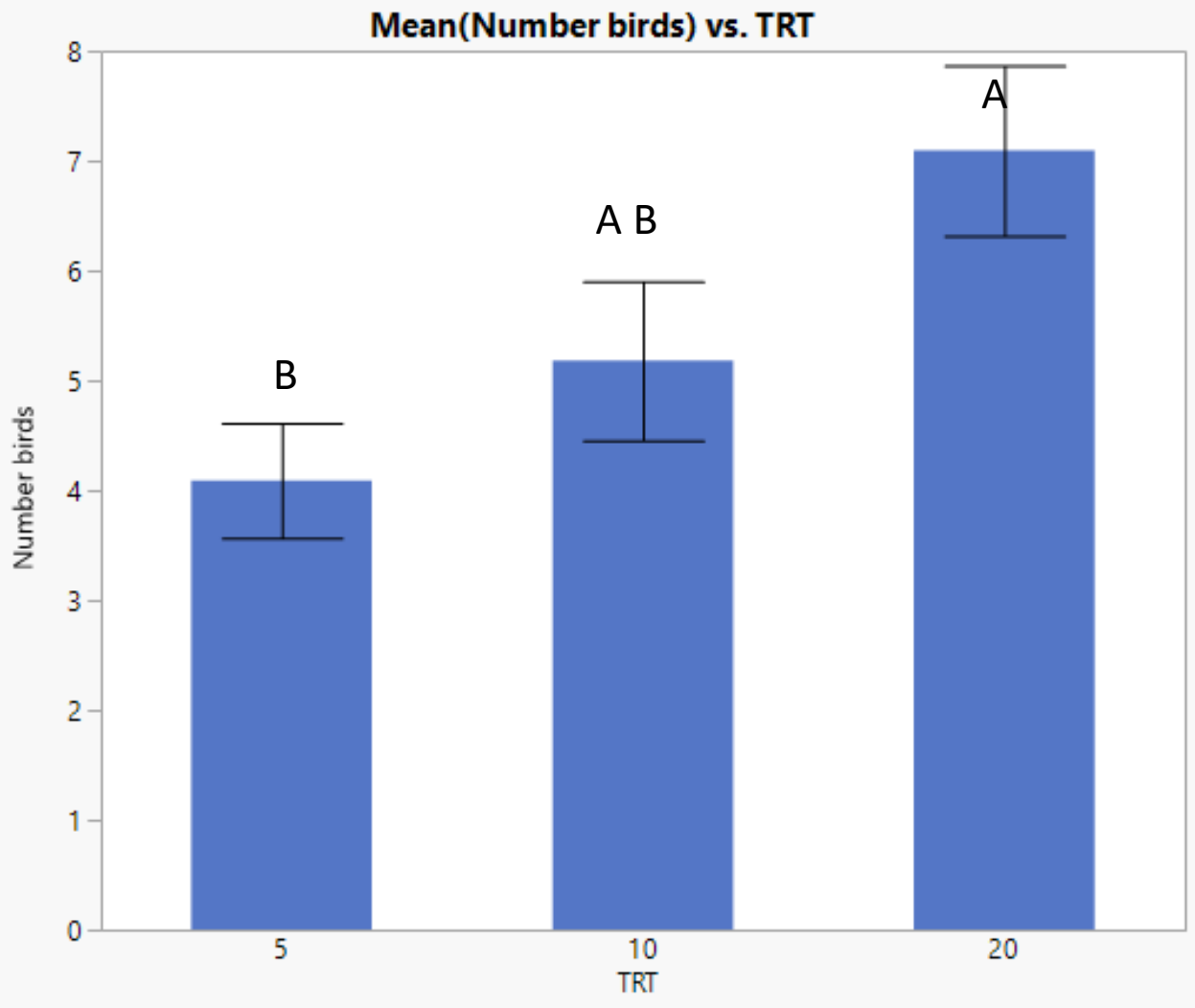


Figure 3. Average number of birds per treatment every 5 minutes during one hour before the light off (error bar is constructed using on standard error from the mean (pooled harmonic mean).

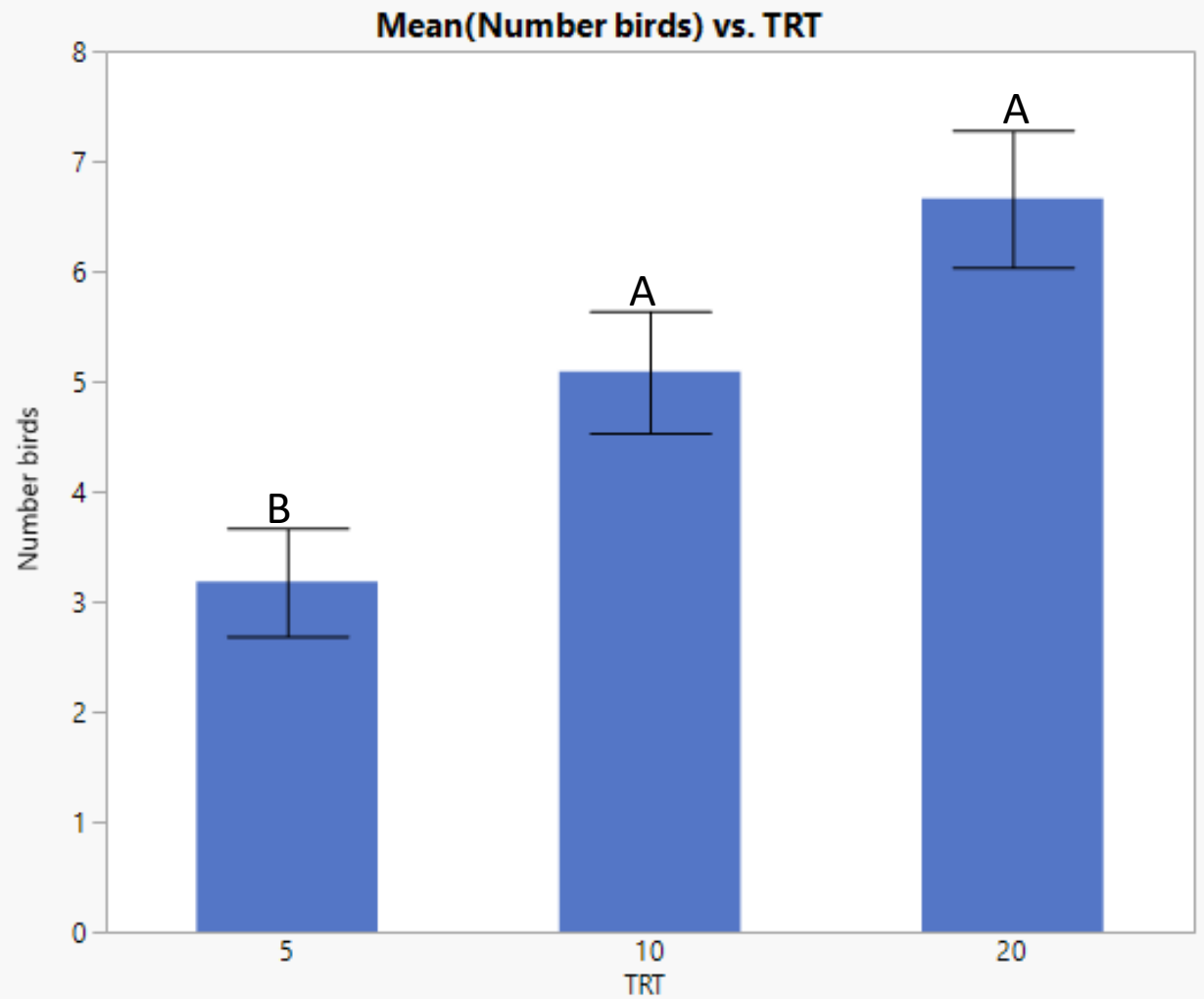
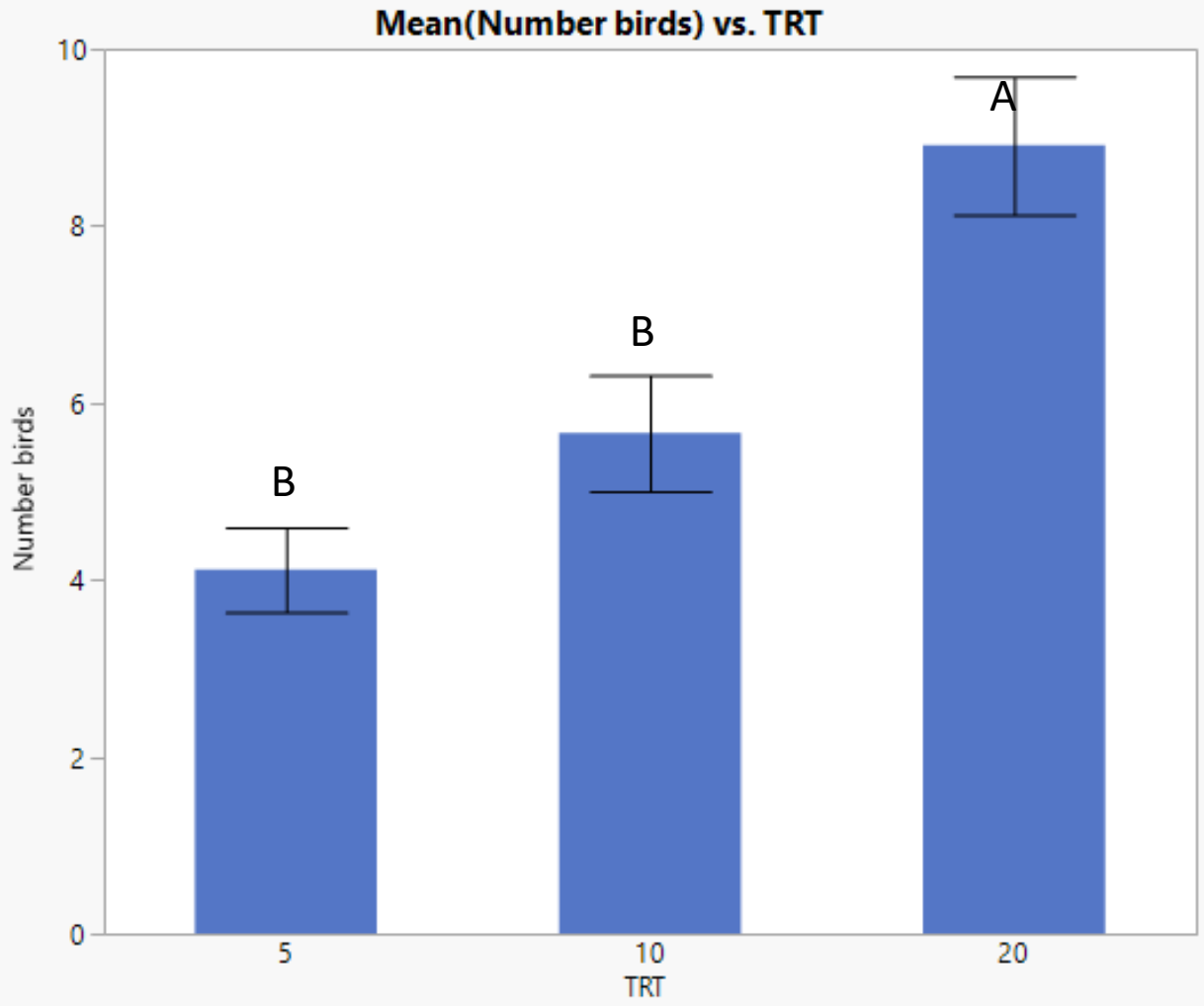


Figure 4. Average number of birds per treatment every five minutes during one hour after light on (error bar is constructed using on standard error from the mean (pooled harmonic mean).



V. **CONCLUSION**

Light intensity is a key component in broiler management. It has effects on broiler production, health and welfare. The main focus of the present study was to determine if there is a difference in terms of production and/or broiler preference (associated with welfare) among 5 lx, 10 lx and 20 lx. I chose the treatments because 5 lx or less is a common industry practice while 10 lx and 20 lx are higher, but in a range of practical use in commercial production. While in the first trial, like in several others, there was no difference among 5 lx, 10 lx and 20 lx in production parameters, but in the preference trial the broilers preferred to eat and drink under 20 lx intensity instead of 5 lx. This provided evidence that the preference of meat-type chickens is for 20 lx light intensity for feeding. In contrast, a surprising finding was that the preference for meat-type chickens is to congregate at high densities away from feed and at low light intensity (5 lx) in this case in the transit area. A possible explanation of these findings is that they preferred to eat under the brighter intensity could be due to a better identification of the texture and characteristics of the feed and the same intensity is not required to rest or do other behaviors so they move to a dim light intensity area. Therefore it is argued that the requirements for resting and feeding are more complex than establishing a simple minimum light intensity as set forth in regulations. In addition, research is needed to explain the physiological mechanism that is behind the preference behavior, and the influence of light intensity on activity and behavior within the range of commercial feasible intensities (5 lx to 20 lx) remain ambiguous and thus more research is required.

Since higher light intensity levels are viewed by the general public and animal welfare organization as an improvement in broiler welfare, the findings of this research suggest strongly that is possible to use a light intensity of 20 lx instead of the common practice of 5 lx without

affecting bird performance and economic profits, but improving the consumer opinion about broiler welfare.

This study opens a new debate that animal welfare must be asses not only in terms of production, physiology and/or health, but also preference and this novel system gives the tools to evaluate it.

APPENDIX

UNIVERSITY OF ARKANSAS

Office of Research Compliance

MEMORANDUM

TO: Karen Christensen

FROM: Craig N. Coon, Chairman

DATE: 7/10/15

SUBJECT: IACUC Approval

Expiration Date: Jul 14, 2018

The Institutional Animal Care and Use Committee (IACUC) has APPROVED your protocol 15067 : " Effect of Feed Additives and Equipment on Performance of Commercial Broilers" with the start date of July 15, 2015

In granting its approval, the IACUC has approved only the information provided. Should there be any further changes to the protocol during the research, please notify the IACUC in writing (via the Modification form) prior to initiating the changes. If the study period is expected to extend beyond Jul 14, 2018 you must submit a newly drafted protocol prior to that date to avoid any interruption. By policy the IACUC cannot approve a study for more than 3 years at a time.

The IACUC appreciates your cooperation in complying with University and Federal guidelines involving animal subjects.

CNC/aem

cc: Animal Welfare Veterinarian

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