Engenharia Agrícola

ISSN: 1809-4430 (on-line)

www.engenhariaagricola.org.br

Review Paper
Doi: http://dx.doi.org/10.1590/1809-4430-Eng.Agric.v43n4e20230023/2023

POULTRY FARMING AND LIGHTING: A REVIEW ON THE IMPORTANCE OF LIGHTING IN BROILER CHICKEN AVIARIES

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KEYWORDS

Poultry farming, lighting, broiler chicken.

ABSTRACT

Brazil stands as a significant economic power in agribusiness, particularly in poultry farming. Broiler chicken production has been developing and evolving in the country for many decades. From these advancements, studies have shown that lighting can be directly related to the well-being and development of the birds. Proper lighting programs can enhance the birds' production capacity while providing a pleasant quality of life. This aids in avoiding psychological disturbances caused by poor environmental conditions, such as cannibalism or skeletal malformation. In this context, this paper aims to present some historical data about Brazil and the onset of poultry farming, the relationship between poultry farming and lighting, and some concepts related to lighting.

INTRODUCTION

In Brazil, raising chickens for personal consumption has been a traditional activity since the 1930s. During this time, families owning rural areas would breed and consume chickens solely for subsistence, and if there was surplus, marketing it was the next step (Silva et al., 2021).

Poultry farming is deemed a crucial economic sector for the national agribusiness. Currently, Brazil ranks among the top two global powers in the production and exportation of chicken meat. This positive outcome arises from the restructuring of the industrial sector, employing new technologies, and enhancing systems for more efficient development (Souza et al., 2019).

Brazil greatly benefits from chicken meat production, where the consumption of this animal protein is directly linked to a specific dietary intake, alongside the rise in population income and urbanization of cities (Rodrigues et al., 2021).

Studies indicate an improvement in chicken performance with the provision of artificial lighting, considering a regular program that includes 24 hours of light during the initial two days, subsequently reducing to a 16-hour program (Figueiredo, 2022).

The lighting design is of paramount importance and should be handled carefully and efficiently. Lighting is intrinsically tied to the development of activities, as visual perception largely comes from receiving information through light (Rezende & Lisita, 2014).

Poultry farming in Brazil

Today, over 150 countries benefit from the exportation of Brazilian chicken meat. Brazil holds a prominent position owing to the quality of genetic improvement, management quality, among other factors. In 2017, the Brazilian Association of Animal Protein (ABPA) reported that Brazil produced 12.90 million tons of chicken meat in 2016, with 34% of this amount destined for export (Pereira et al., 2019).

Over time, Brazil carved out its space as an exporter of broiler chickens on the global stage, evident from the numbers presented. From 1961 to 2003, Brazil saw a 1000% increase in production, reaching a mark of 10.5% of the global chicken production. Over the last 30 years, Brazil stood out with the enhancement of its technology in the production and breeding of chickens, significantly boosting productivity (Liboni et al., 2013).

The emergence of industries in the poultry sector took place in the 1950s, with aviaries beginning to be structured with new methods of broiler chicken breeding. Concurrently, Brazil was undergoing research in institutes to improve combating poultry diseases. This period marked

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Area Editor: Héliton Pandorfi
Received in: 2-14-2023
Accepted in: 9-14-2023

the initiation of the first associations related to poultry farming (Schmidt & Silva, 2018).

Broiler poultry farming holds great importance in the agro-industrial supply chain. It comprises various technological investments, besides generating a significant number of jobs. It possesses a quick production cycle, considering that chicken protein is low-cost, which advantageously attracts various social classes for consumption (Reck & Schultz, 2016).

Brazil positions itself as one of the largest chicken meat exporters globally. Studies suggest that this was possible due to three indispensable factors: low cost, product quality, and sanitary status. The combination of these three factors places Brazil superior among other protein suppliers (Schmidt & Silva, 2018).

The production chain in broiler chicken aviaries is one of the most important sectors in the Brazilian agro-industrial field, marked by various technological evolutions. Among these, the genetic evolution, mental health of the birds related to hygiene and vaccinations, nutrition, with a good linear production program, bird management, with more modern equipment and facilities, and the control and climatization of the aviary stand out. All these factors have resulted in a significant highlight in the import and export market, positioning Brazil as a global standout in chicken supply (Schmidt & Silva, 2018).

Poultry farming and lightning

The breeding of broiler chickens shows rapid growth and high genetic potential, but for this to happen, adequate conditions must be provided for the birds to achieve optimal performance. Birds express themselves through their behavior, which is influenced by the characteristics of the breeding environment. Factors related to lighting such as illuminance, wavelength, and lighting programs directly affect the physiological development of the bird (Lucena et al., 2020).

Lighting programs are directly related to the well-being of broiler chickens. Many bird species have a circadian rhythm, which is a biological process displaying an endogenous oscillation over a 24-hour period, functioning like a body clock, alternating cycles between sleepiness and alertness. This circadian rhythm, controlled by the birds' hypothalamus, is influenced by external signals including light and temperature (Arowolo et al., 2019).

In the breeding and production of broilers, various lighting systems with different proposed intensities are used. The primary objective is to create the best environmental condition for the bird to develop, aiming to gain more weight without suffering metabolic alterations. One of the most analyzed factors among these systems is photoperiod, which is the number of hours the bird is exposed to light (natural ou solar) (Lima et al., 2014).

With technological evolution, new climate control systems have brought many changes regarding environmental comfort in the poultry sector, positively affecting the development of birds and also the health of the flock. However, a downside of this technological evolution is considered to be the increase in rates regarding electrical energy (Santos et al., 2019).

Lighting schedules are categorized into three classes: intermittent, increasing, and constant. In the intermittent light system, light alternates between dark and illuminated within a day, with the goal of controlling and synchronizing the birds' food consumption during this process. The increasing process employs lighting according to the growth of the bird, not forcing too much in the initial period to avoid affecting the bird's skeletal evolution, with a focus on reducing feed, then after skeleton formation, it will be able to keep up with the growth and weight gain of the chicken. Meanwhile, the constant light program uses the same lighting system throughout the breeding period, with birds consuming the same amount of feed throughout the process (Liboni et al., 2013).

Birds' eyes are vulnerable organs and influenced by external factors, including light intensity. Very high or very low intensities have caused discomfort issues in the animals. In broilers, studies point out that continuous exposure to high-intensity light early in life can result in severe hypermetropia, corneal flattening, and avian glaucoma (Arowolo et al., 2019).

Artificial lighting and lighting programs are a vital component in the commercial poultry sector. Light variation, levels of light intensity, and photoperiods are used to control bird behavior, improving their psychological well-being. However, research to provide better information about indoor lighting in commercial poultry houses is still very recent (Linhoss et al., 2023).

Sensitivity to light varies between humans and birds, with birds' visible spectrum ranging from ultraviolet (UV) to infrared (IR) waves. The explanation for this is that birds perceive light through their eyes and also the pineal gland, also called the third eye, which is precisely responsible for the bird's sexual activity and also its circadian cycle (Santos et al., 2019).

Illuminance plays a crucial role concerning the health of broiler chickens. Studies indicate that low lighting aims to control aggressive behavior of birds, including cannibalism. High-intensity lighting, on the other hand, can enhance their activity (Lucena et al., 2020).

Light intensity affects the behavior of broiler chickens. Aspects related to lighting such as light intensity, wavelength, photoperiod, spectral distribution, spatial distribution of lamps on site, among others, also affect the quality of production. The lack of exposure to ultraviolet rays for birds kept in sheds can harm their behavior and growth, as, unlike humans, birds can see in this spectral range (Pereira et al., 2012).

Traditional lighting systems in poultry houses have been replaced with a new technological system. This is the modern dark house poultry production system. It features equipment with lighting control, and is also able to alter temperature, pressure, among other factors affecting bird breeding (Santos et al., 2019).

The lighting program chosen to be used in broiler chicken production is one of the main factors that interfere and impact the well-being and productivity of the bird. There are four elements that are considered important in choosing the lighting system: lighting program, its distribution within 24 hours, the color and wavelength of the chosen light, and the intensity of the light. Given that birds are controlled by light, facilitating activities such as feeding and digestion, body temperature, and reproduction (Arowolo et al., 2019).

Broiler chicken are considered a photosensitive, thus their behavior and well-being are affected and influenced by environmental lighting. This perception of light occurs through the retina, located in the bird's eyeball, forming images and differentiating colors, allowing interaction between the bird and the environment, potentially affecting their behavior and growth (Seber et al., 2018).

It is proven that light intensity, lamp distribution, and color temperature encourage broiler chickens to feed and hydrate. When brightness is excessive, a temperature increase occurs, causing the birds to cluster in the shed in less affected regions, rendering areas with higher lighting ineffective (Faustino et al., 2021).

The use of LED lamps, or light-emitting diode lamps, presents an energy-saving opportunity, making the process and improvement of the sector viable. Concerning the advantages of using LEDs compared to fluorescent and incandescent lamps, studies point out better energy efficiency, longer lifespan, resistance to humidity, and the availability of choice in supplying certain wavelengths throughout the breeding cycle, besides a lower dimming cost (Seber et al., 2018).

Lighting systems using artificial lighting are of paramount importance in commercial poultry houses. The variation of lighting, along with the right choice of light intensity and correct photoperiods, help control bird behavior, directly affecting their well-being (Linhoss et al., 2023).

Lightning concepts

Artificial lighting is a tool used in poultry farming. Its main goals are to improve feeding and water consumption, enhancing bird growth and consequently production. Lighting programs are designed according to changes in bird growth metabolism. They can vary depending on the desired final result. One of the major challenges in broiler production is directly related to energy consumption, which consequently increases production costs (Lima et al., 2014).

In turn, LED lamps possess various qualities, among them a longer lifespan, which, unlike incandescent bulbs, do not burn out easily. Instead of burning out, they weaken over time. LEDs do not emit ultraviolet or infrared rays, and they also do not heat up. Besides these advantages, it's also noted that LED lamps have a wide variety of colors and sizes, in addition to lower energy consumption (Borges, et al., 2017).

Currently, using LED technology in broiler production has shown significant improvements, with high luminous efficiency and less energy consumption. These lamps have a longer lifespan compared to incandescent and fluorescent bulbs. Bibliographic studies confirm that light quality, intensity, and color temperature can interfere with the behavior and development of birds. That is because the photosensitive parts of the birds' brains are directly connected to the pineal gland, which is stimulated by light (Lima et al., 2014).

Light Emitting Diode (LED) lamps are more economical than fluorescent and incandescent lamps, one of the reasons is improved energy efficiency, a superior lifespan, more options regarding lamp characteristics, and easy dimmability (Seber et al., 2018).

It has been proven that, in a lighting system, the replacement of mercury lamps with LED lamps is a viable investment, despite the high initial cost of switching to LED lamps, there is a short financial return time due to reduced maintenance and energy consumption (Borges et al., 2017). (Borges et al., 2017).

Furthermore, switching a lighting system to light-emitting diodes is an economically accessible investment, the high apparent cost at the beginning returns in a short time, due to energy savings generated by LEDs and low maintenance (Borges et al., 2017).

Lightning projects related to poultry farming

A lighting project requires calculations to reach an optimal result, defining number of lamps and fixtures needed to meet environmental needs. The two most used methods for performing these calculations are the Lumen Method, approved by the International Commission on Illumination (CIE), and the Point-by-Point Method, which is based on Lambert's Law (Juliana & Kawasaki, 2016).

When discussing luminary calculations, there are four major aspects to consider: color reproduction, lighting balance, light intensity, and glare assessment. These four criteria are related to visual comfort, which is interconnected with the user's health (Marchiori, 2017).

Every environment requires a certain amount of illuminance. Lighting should be installed at specific points. The projected illuminance must undergo calculations, and results cannot be lower than the minimum amount of lighting designated for that task. In this sense, manufacturers must provide data regarding quantities and units of lighting for calculations (Moura, 2018).

Both the Lumen and Point-by-Point Methods can be performed manually. However, with advanced technology, they now can be carried out through specific software for luminary calculations, obtaining more precise results and including various variables to define the best lighting system (Juliana & Kawasaki, 2016).

The Lumen Method is the most used for luminary calculation. It is also known as Luminous Flux Method. Its goal is to determine the ideal amount of lumens for each environment, as each environment, depending on the activity to be performed, has a minimum amount of lux to be achieved. The method also considers the colors of the surfaces and the type of lamp chosen (Marchiori, 2017).

According to Juliana & Kawasaki (2016), the formula used for calculation is as follows:

$$\Phi = E * S / \mu * d \quad (1)$$

Where:

Φ: luminous flux in lumens;

E: illuminance or illumination level in lux;

S: area of the enclosure in m² (square meter);

μ: coefficient of use,

d: depreciation factor or coefficient.

The Point-to-Point method is used to determine the amount of light between the light source and the selected object. More precisely, if the distance between the object to be illuminated and the source is at least five times greater than the dimension of the lamp, this method is utilized. Typically, this method is applied to lamps with narrow light beams, like dichroic, PAR, and some LEDs. However, it does not account for surfaces in the environment, making calculations much more complex in settings with multiple light sources (Juliana & Kawasaki, 2016).

Light management tools are crucial in commercial broiler chicken production. Reviews have suggested that using intermittent lighting with extended photoperiods, rather than constant or continuous lighting, improves poultry performance. Moreover, adjusting light intensity, color, and wavelength can enhance production. Evaluations have also shown that maintaining a light intensity above 5 lux, following the initial few days of life, boosts productivity and promotes well-being to birds (Arowolo et al., 2019).

Over time, broiler chicken production systems have become increasingly technological, with imports of more modern equipment and automation technology to achieve higher energy efficiency aimed at economic improvement. One of the best examples is the Dark House system, which has shown improvement compared to conventional systems (Mattioli et al., 2018).

Literature proves that several factors influence proper feeding and hydration of birds, including light intensity, color temperature, and placement of lamps. Excessive brightness raises temperature, causing birds to gather in less illuminated areas of sheds. As a result, areas with more illumination are underutilized (Faustino et al., 2021). A well-designed lighting program for broiler chicken aviaries can improve the environmental efficiency where birds are housed, while also considering their well-being. Birds exposed to light levels between 20 and 5 lux show more comfort behaviors, demonstrating better well-being when the lighting system provides adequate conditions (Lucena et al., 2020).

Different terms and units of measurement are crucial in lighting and luminaire design; understanding them is essential to attain the desired efficiency in a proposal for illuminating a specific place (Maia et al., 2011). Among these terms, one can cite:

Luminous intensity: it refers to the amount of light, or luminous flux, emitted by light sources in a specific direction within a solid angle. It is measured in Candela (cd) (Niskier & Macintyre, 2000 apud Moraes, 2006).

Luminous flux: it represents the total amount of light emitted or observed, often described as luminous power. It encompasses the energy emitted or reflected in all directions (Niskier & Macintyre, 2000 apud Moraes, 2006).

Illuminance: it measures the amount of luminous flux (light) falling on a surface area per square meter, and its unit of measurement is Lux (E). A luxmeter is a device used to calculate illuminance by evaluating the quantity of lux on a surface, thus helping to understand the light distribution across a given area (Niskier & Macintyre, 2000 apud Moraes, 2006).

Luminance: it can be considered as luminous intensity that reaches the user through reflection; this reflection can come through objects or light sources (Niskier & Macintyre, 2000 apud Moraes, 2006).

Luminaire efficiency: it is a formula where the ratio of lumens emitted by the luminaire is divided by lumens emitted by the lamps within it (Niskier & Macintyre, 2000 apud Moraes, 2006).

Luminous efficiency: it can be considered as the relationship between luminous flux emitted and electric energy consumed per unit of time by a light source. It basically means that the higher the efficiency of a lamp, the lower will be its consumption in watts. The unit of measurement is lm/W (Niskier & Macintyre, 2000 apud Moraes, 2006).

Color rendering index (CRI): it reflects how accurately a light source reproduces the colors of objects it illuminates. As a result, the higher the CRI, the closer will the object or the surface be represented to its original color. This index is measured in percentage (Niskier & Macintyre, 2000 apud Moraes, 2006).

Color temperature: it is defined by the color that a light source emits, measured in Kelvin (K); the higher the color temperature, the clearer it will be represented. They are treated as warm and cold temperatures; however, it is not related to temperature in degrees but temperature of colors. Below, Table 1 displays the color temperatures and light sources, while Table 2 shows the units of measurement and magnitudes regarding lighting (Niskier & Macintyre, 2000 apud Moraes, 2006).

TABLE 1. Quantities and units of measurement for lighting.

Factor	Symbol	Unit of measure	Concept
Total installed power or energy flow	P	W or kW for power, and J Wh for energy flow	"Sum of the power of all devices installed in the lighting"
Power density	D	W/m^2	"Total installed power in watts per square meter of area"
Relative power density	Dr	W/m^2 per 100 lx	"Total installed power density for every 100lx of illuminance"
Luminous flux	ϕ	lm (lumen)	"Amount of light emitted by a source at nominal operating voltage"
Lamp energy efficiency	ηw or K	lm/W	"Lumens generated per watt consumed by each lamp, also called 'Luminous Efficiency'"
Luminaire efficiency	ηL	dimensionless	"Ratio of the Luminous Flux emitted by a luminaire, relative to the sum of the individual fluxes of the lamps operating outside the luminaire"
Room efficiency	ηR	dimensionless	"Relationship of the reflectance values of the ceiling, walls, and floor, with the Luminaire Distribution Curve and the Room Index"
Room index	K	dimensionless	"Relationship among length, width, ceiling height, working plane height, and luminaire pendant height"
Utilization factor	Fu	dimensionless	"Final Luminous Flux that falls on the work plane, that is, ηL x ηR"
Depreciation factor or maintenance factor	Fd	%	"Depreciation of the lamp luminous flux and accumulation of dust on lamps and luminaires"
Illuminance	E	Lux (lx) = lm/m2	"Light emitted by a lamp in relation to the surface it illuminates"
Average illuminance (Em)		Lux (lx) = lm/m2	"It is considered the average illuminance, as the luminous flux does not distribute evenly at all points"
Luminous intensity	I	Cd (candelas)	"Luminous Flux irradiated towards a given point"

Luminous distribution curve	LDC	Cd x 1,000 lm	"Representation of Luminous Intensity in all angles it is directed on a plane"
Luminance	L	Luminance (L): Candelas per square meter (cd/m²) or foot-lamberts (fL).	"Luminous Intensity emanating from the surface, conveying a sensation of brightness"
Color rendering index	CRI or RA	Cd/m2	"Color reproduction of a lamp varying from 0 to 100 based on sunlight (index 100)"
Color temperature or correlated color temperature	T or CCT	K (Kelvin)	"Color appearance of the lamps"
Luminous flux factor	LF	%	"Ballast depreciation due to luminous flux, obtained by the nominal luminous flux"

Source: (Rezende & Lisita, 2014).

CONCLUSIONS

This literature review highlights the significant role of poultry farming in Brazil's agribusiness sector, tracing back to small family productions in the mid-1930s. Driven by commercial demand and societal shift towards chicken protein, advancements in studies and technologies propelled Brazil to become a global leader in chicken exportation. Research reveals that proper lighting in sheds is crucial for chicken development. A well-planned lighting program, ensuring comfort and well-being for the birds, enhances production and protein quality, leading to increased profits. This positive impact extends to the market, boosting the country's economy, benefiting workers, investors, and ensuring a quality life for the birds during their breeding process.

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