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Review Article

Influence of Daylength, Light Color, Light Intensity, and Sources on the Performance of Growers, and Layers of Different Strains of Chicken: A Review

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Abstract

The productive and reproductive performances of growing and laying chickens are affected by the genetic background of the birds, the environment where they are exposed, and the interaction effects of genotype by the environment. Among many environmental factors, the study concentrates on the effect of day length, light intensity, color, and source of light on growth, egg production, reproductive performance, and quality of eggs. Light levels (intensity or illuminance), colors, the duration of light (photoperiod), and the source of light are essential factors in poultry production. Intensity influences cannibalism, and aggression, along with feed and water intake, while the photoperiod influences reproductive and egg production cycles, total feed intake, and growth rate. Even though these kinds of information are very important in the poultry business, the availability in Ethiopia is very limited. Hence the objectives of this review study are to provide evidence-based information related to these parameters to poultry value chain actors and increase their profitability and resilience to external shocks. The result of this review study revealed that photoperiod does have its own effects on the growth, reproductive performance of pullets, and egg-laying percentage. During the growth phase of the chicks, light hours start at 24 hrs during the first week and decrease to nine hours per day at the age of six weeks and remain flat till the age of 17 weeks. However, exposing birds to higher photoperiods beyond 17 hours per day after 17 weeks will result in prolapse of the reproductive tract, smaller egg size, diminished lifetime egg output, encourage birds for cannibalism, and increased overall costs of production by extra lighting. During the laying phase, increasing the photoperiod (artificial lighting by 2 - 4 hrs) beyond the natural day length on laying hens indicated that, it can increase egg production by 20 - 30%. If the producer wants early egg production, a high total egg number, and moderate egg weight, he should use the quick step-down/step-up light arrangements. Light hours can be reduced by 15 - 30 minutes per week during the growth phase till they reach a constant day length. In a step-up lighting program, similarly, the day length of birds should be increased by 15 - 30 minutes per week till they reach 16 hours per day. Similarly, light color does have it's own effect on the performance of birds. Birds exposed to red and white color lights do produce more eggs as compared to their counterparts exposed to blue and green lights. On the other hand, broilers exposed to blue light colors gained better body weight as compared to green light. Broilers exposed to red light had increased immunity titer levels as compared to broilers exposed to white, blue, and green light. The response of birds to light intensity indicated that the light intensity should be 30 lux (3 foot-candles) during the first week of age, after which it can be reduced to 5 to 10 lux (0.5 to 1.0 foot-candles) in cages or to 15 lux (1.5 foot-candles) when grown on the floor. The higher light intensity for floor-grown birds will allow the birds enough light to navigate their environment. In cages, there should be 10 lux (1.0-foot candles) at the feeder height, and 5 lux (0.5-foot candles) inside the cage. When the effect of the light source is evaluated, LED lamps are superior in terms of their technical performance, and economics compared to incandescent, and fluorescent lamps even though the initial cost of LED lamps is on the higher side. Light-Emitting Diodes Light bulbs (LEDs) are currently the most efficient source of light since they use 90 percent less energy than standard lighting and last up to 25 times longer. LEDs light up quickly, and they don't contain any toxic materials that can operate in cold temperatures without flickering. LED lamps did not have any negative impact on the production, and egg quality of the laying hens. Therefore, poultry farmers should consider the photoperiod, light color, light intensity, and source of light during growing as well as the laying phase of their chickens for the betterment of their businesses.

Keywords: *Artificial Lighting; Light Color; Light Intensity; Photoperiod; Sources of Light*

Introduction

The productive and reproductive performances of growing and laying chickens are affected by the genetic background of the birds in question, the environment where they are kept, and the interaction effects of genotype by the environment [1]. Two major indices of measuring the profitability of raising chicken in an egg-type chicken are the total number of good-quality eggs produced, feed efficiency, mortality percentage, growth performance, and uniformity. The same holds true in broiler farm profitability but in this case, it is the amount of meat produced per unit of feed consumed, and mortality percentage which plays a major role [2]. Many factors can adversely affect egg production, reproductive performance, and quality of eggs. Among many factors, are feed consumption (quality and quantity), water intake, intensity, duration, color, sources of light received, parasite infestation, disease, numerous other management, and environmental factors [2]. This review study is therefore, focusing on one of the constraints, that is day length (light hours), color, intensity of light, light source for growth, egg production, reproductive performance, and quality of eggs. Hens need a minimum of about 14 hours of day length to maintain egg production. The intensity of light should be sufficient to allow a person to read a newspaper at the bird level [2]. The decreasing day length during the fall and shorter day lengths in the winter would be expected to cause a severe decline or even cessation, in egg production unless supplemental light is provided [2].

Light is an important aspect of an animal's environment. Avian species as well as mammalian species respond to light energy in a variety of ways, including growth and reproductive performance [3]. The value of regulating the photoperiod of poultry, and livestock to stimulate reproduction has been recognized for many years and is used regularly by commercial poultry and livestock farmers. For chickens there are three major functions of light: 1. to facilitate sight, 2. to stimulate internal cycles due to day-length changes, and 3. to initiate hormone release [3]. Light levels (intensity or illuminance), colors, the duration of light (photoperiod), and the source of light are essential factors in poultry production [4]. Intensity influences cannibalism and aggression, along with feed and water intake, while the photoperiod influences reproductive and egg production cycles, total feed intake, and growth rate [4]. Light intensity at the working site (bird level, egg collection table, work-bench level, etc.) is measured in lux or foot-candles (10 lux equals about one foot-candle). Typical light levels found in broiler and layer operations are about 10 to 20 lux (1 to 2-foot candles) [4].

The lighting program (day length and light intensity) to which a flock of growing chicks, and laying hens is subjected during the growing and production phase is a key factor in determining the onset of sexual maturity and egg production [5]. Research has shown that the color of light can also have many different effects on behavior, growth, and reproduction performance in poultry [5]. Birds sense light through their eyes (retinal photoreceptors) and through photosensitive cells in the brain (extra-retinal photoreceptors). Since long wavelengths of light (towards the red end of the spectrum) penetrate the skin and skull more efficiently than short wavelengths, it has been observed that growth and behavior are linked to retinal photoreception (and shorter wavelengths) whereas the reproductive performance has been linked to extra-retinal photoreceptors. From these observations it has been reported that blue light has a calming effect on birds, however, red has been used to reduce cannibalism and feather picking [5]. It has also been shown that blue-green light stimulates growth in chickens while orange-red stimulates reproduction [3].

Birds are more sensitive to light compared to humans. Hence, effective Lighting management is essential in poultry husbandry. Lighting can influence the onset of lay, early egg size, and the total number of eggs produced in a lifetime. Lighting varies from differing environments including both open and closed houses. Care should be taken to maintain light intensity at the same levels or even higher during the last weeks of rearing. Egg production is associated with the length, and intensity of the light received by the bird daily. Light stimulates the anterior lobe of the pituitary gland through the optic nerve for the release of FSH (Follicle Stimulating Hormone) and LH (Luteinizing Hormone). Light energy also penetrates through the skull, skin, and feathers. FSH increases the growth of the ovarian follicles. Upon reaching maturity, the ovum is released by the action of LH [3,5-9]. Estrogen secretions from the developing follicles are responsible for the development, and enlargement of the oviduct to allow for the passage of the yolk and the eventual formation of the egg. Estrogens also cause the spread of the pubic bones (through which the egg passes when laid) and enlargement of the vent necessary for oviposition, or expulsion (laying), of the egg [8,9].

Egg production is stimulated by daylight; therefore, as the days grow longer production increases. In open houses, found commonly in the tropics, artificial lighting may be used to increase the laying period. Artificial lighting is one of the most powerful management tools available to commercial layer producers. Light is important for poultry for many reasons. Controlling the light environment can improve egg production and growth. Light influences bird behavior, metabolic rate, physical activity, and physiological factors such as reproduction [10]**.** Light color refers to wavelength and frequency and is important to avian reproduction because minimal light intensity is needed to elicit a photo-stimulatory response. Producers have clear requirements for both light color for brooding and light color for the laying flock [11].

Most vertebrates perceive light via the eye. Light enters the eye, and it is projected onto a light-sensitive panel of cells, the retina. So-called cones and rod cells in the retina detect and convert light into neural signals for vision [12,13]. The visual signals are then transmitted to the brain via the optic nerve and influence the behavior and sexual activity of the birds. Furthermore, the pineal gland and the hypothalamus have some photoreceptors. Their stimulation influences the bird's life as well. The visual system of birds differs from that of mammals, and humans [13]. Artificial light sources used in rearing facilities for pullets, and laying houses include incandescent lamps, tubular fluorescent lamps, and more recently energy-saving lamps (LED). Modern, low-cost LED (Light Emitting Diodes) technology is set to become more widespread in the future, especially if they will be further developed to emit a brighter spectrum of light [13]. In order to prevent stress-induced behavioral abnormalities, the light intensity in light-proof pullet and layer housing is restricted for commercial reasons to about 5 Lux (rearing) and about 10 to 15 Lux (production) when the hens reach four weeks of age [13].

The light frequency depends on the light source. Fluorescent tubes and energy-saving lamps operating in the low-frequency range (50 Hz alternating current) are considered unsuitable for fowl. Because of their sharp vision, hens perceive the flicker of the light, which can have adverse effects on their behavior (nervousness, feather pecking, and cannibalism). Since incandescent lamps cannot convert electrical power to light as efficiently as other types of lamps, they will soon be banned in most developed countries of the world [13].

The lighting program (day length and light intensity) to which a flock of laying hens is subjected during the growing, and production phase is a key factor in determining the onset of sexual maturity, and egg production. Lighting programs for pullets kept in windowless shads can be designed to guarantee optimal growth and efficient preparation for the laying period, largely independent of the season. The "golden rule" to follow in designing lighting programs for pullets is that they should never experience an increase in day length until the planned light stimulation starts, and never experience a decrease in day length during the production cycle. Following this principle, the day length is gradually reduced after placement of the day-old chicks in the rearing farm; after the minimum is reached, a phase of constant day length follows, and finally light hours are gradually increased to stimulate the onset of lay [13]. The so-called "step down" procedure in the early days of the chick's life can be used to make the pullets more sensitive to light. After reaching 10 to 8 hours per day, the birds are kept on constant day length for some weeks. Any step-up procedure or increase in day length when birds get to an age of 14 to 15 weeks will stimulate sexual maturation. A quick step-up will induce an earlier onset of egg production, while a slow step-up will delay the onset of lay [13]. The combination of quick step-down and quick step-up lighting is most effective for achieving the early onset of lay; slow step-down and slow step-up will delay it. Many scientific trials and practical experience with different strains of layers have confirmed that the number of eggs and egg weight can easily be influenced by utilizing this tool. Parent flocks should never be exposed to the quick step-up/step-down program, because small eggs at the beginning of the laying period cannot be used as hatching eggs, and therefore, undesirable [13].

On the other hand, Ethiopia has a small but growing number of medium and large-scale intensive broiler and layer farms located in and around major cities which demands additional light hours for better performance [14]. These commercial-oriented poultry businesses need light at different levels and intensities. However, the information available in Ethiopia related to day length, intensity of light, color, and source of light effects is very scant. Therefore, knowledge of the photoperiod, intensity of light, color, and source of light is very important to make their businesses more profitable and resilient. Hence the objectives of this review study include:

- By reviewing the global experience related to the application of photo periods, light intensity, color, and source of light at different stages of poultry enterprises to avail evidence-based information to poultry farmers in Ethiopia.
- By sharing the global experience on different light parameters, to advise poultry farmers to apply the available information on their farms for improvement in their performance and increase the overall profitability of their business.

Effects of photoperiod on pullets, and layers performance

Artificial lighting is one of the most powerful management tools available to commercial layer producers. Light is important for poultry for many reasons. Controlling the light environment can improve egg production and growth. Light influences bird behavior, metabolic rate, physical activity, and physiological factors such as reproduction [10]. Light is received by the eye and hypothalamus. Egg production is associated with the length and intensity of the light received by the bird daily. Light stimulates the anterior lobe of the pituitary gland through the optic nerve for the release of FSH and LH. Light energy also penetrates through the skull, skin, and feathers. FSH increases the growth of the ovarian follicles. Upon reaching maturity, the ovum is released by the action of LH [6].

Light duration has effects on both growing chicken and layers. In the growing period, the effect of increasing the light period can increase the age at sexual maturity; increase the number of eggs laid during the first half of the egg production (but not in the total number of eggs laid) and increase the size of the first eggs produced. If the pullets come into production too early, they may have problems with prolapse, which can cause health problems across the flock. Also, the hens may lay smaller eggs throughout the production cycle [5,7]. On the other hand, when the lighting period increases during the laying period, birds tend to produce more eggs due to the release of FSH and LH from the pituitary. The brightness of light also has an influence on egg production. In practical conditions, 1 ft candlelight intensity is needed in layer houses. In a multi-duck cage system, a minimum of 0.5-foot candlelight intensity is needed at the lower deck. For maximum egg production, 16 hours of light is needed during the peak egg production period. Reducing photoperiod during the laying period seriously affects egg production. The artificial light can be given either in the morning, evening, or both morning and evening but is preferred during the morning to make the birds stress-free [5,7,15].

The study was conducted to investigate the effect of three different photoperiods (13, and 16, 19 hours) on some maintenance behavior, and external and internal egg quality traits of layers. One hundred and eight birds of Bovans layers at 25th week of age were used. The birds were divided randomly into three equal groups and each group was subdivided into 6 replicates (6 birds/replicate), where the cage floor spaces were 833 cm^2/bird [16]. The results of this trial revealed that the birds housed at 16 hours of photoperiod/day laid eggs with significantly higher external quality traits, including egg length, egg width, shell weight, eggshell ratio, and shell thickness than other groups. Moreover, egg weight and its surface area were significantly higher in 16 hours of light than in 13 hours. Similarly, most of the internal quality traits, including yolk height, albumen height, yolk weight, and yolk ratio were affected by photoperiod. In addition, there was an increase in most behavioral patterns (feeding, drinking, sitting, and other comfort behaviors) in the 16-hour photoperiod, with significant differences. It was concluded that there is an economic effect of housing layers at different photoperiods [3,16].

The present experiment revealed a significant increase in most of the internal egg quality in 16 hrs of photoperiod compared to the other two, which may be due to the correlation between internal and external quality. Yolk height, albumen height, yolk diameter, yolk weight, yolk ratio, and haugh unit were significantly higher at 16 hrs than at 13 and 19 hrs of photoperiods, respectively [16]. The details of the internal egg quality traits are summarized and presented in figure 1 whereas the external egg quality traits are summarized and presented in figure 2.

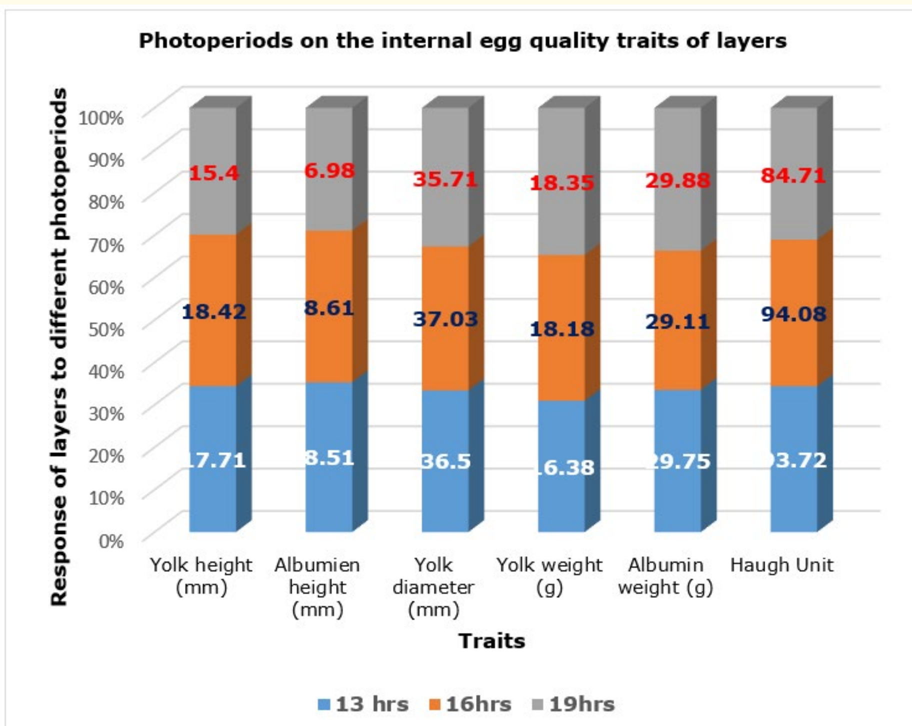

Figure 1: *Internal egg quality traits.*

Source: [16].

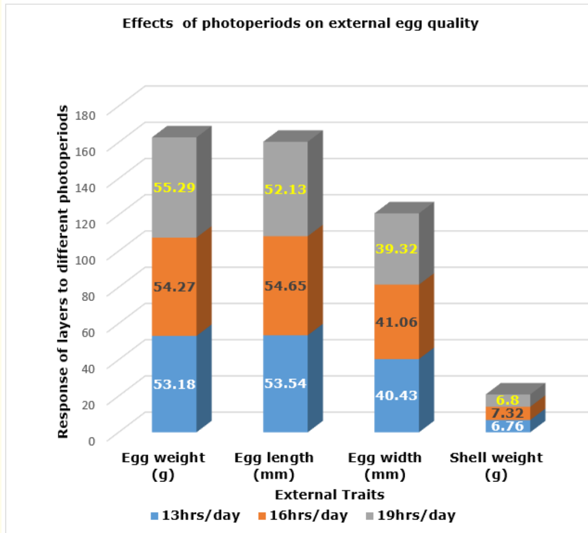

Figure 2: *External egg quality traits.*

Source: [16].

Allowing young pullets to begin laying before they reach 17 or 18 weeks of age is unwise and may produce a condition known as prolapse (also known by the unlovely term "blow-out"). In young birds, this can happen when the bird produces an egg (often a double yolk) that is too large to pass easily through the cloaca, and by straining to expel it she everts the uterus through the vent. This may correct the condition if the other birds have not seriously injured her. Remove the affected bird from the flock. If you keep her in the pen showing a bloody rear, she may become a victim of cannibalism, and may also cause general picking by the entire flock [17].

The so-called "step down procedure in the early days of a chick's life can be used to make the pullets more sensitive to light [18]. After reaching 10 to 8 hours per day, the birds are kept on constant day length for some weeks. The length of the day during this constant period determines the step-down and the following step-up program. The more time the birds have during this constant phase, the more they will eat and grow. The program called step-up procedure or increase in day length will stimulate the sexual maturity of birds when birds reach the age of 14 - 15 weeks. A quick step-up will induce an earlier onset of egg production, while a slow step-up will delay the onset of lay. The combination of quick step-down and quick step-up lighting is most effective for achieving the early onset of lay; slow step-down and slow step-up will delay it. If the producer wants early egg production, a high total egg number, and moderate egg weight, he should use the quick step-down/step-up variant. To get fewer but larger eggs, a slow step-down/step-up variant should be chosen [3,12,18]. The lighting requirement for growing chicks and layers is summarized and presented in figure 3.

Reduce the day length weekly to reach 9 to 10 hours at 10 weeks of age or, if longer, the day length dictated by the greatest natural day length in open or brown-out houses. In Hy-Line Brown and CV-22 varieties, a constant day length of 9 hours may be used to control excessive body weight after 10 weeks of age [5]. The initial light increase should be no less than 1 hour (especially in open houses). Increase the day length by 15 to 30 minutes per week or once every 2 weeks until 16 hours of light is reached. Preferably, the period of

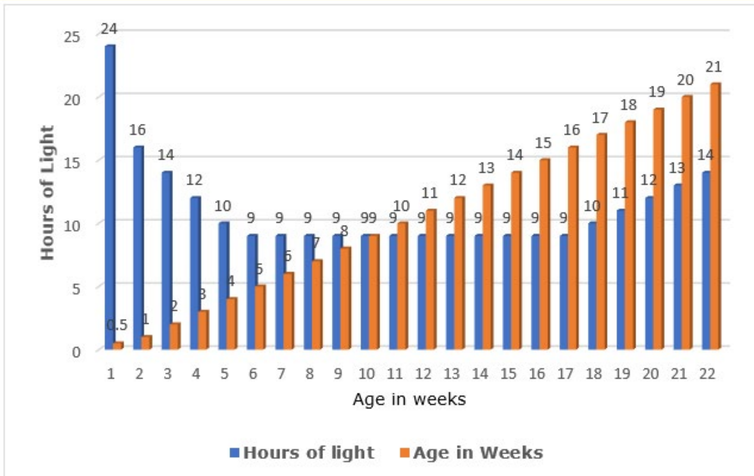

Figure 3: *Required Light hours based on the ages of laying birds.*

Source: [19].

increasing day-length stimulation should last until peak production (i.e. until about 30 weeks of age). The light intensity at housing should be 15 to 30 lux (1.5 to 3.0 foot-candles) in light-controlled houses and 30 to 40 lux (3 to 4 foot-candles) in open-sided houses [5].

Chickens are called long-season breeders, meaning that they come into production as days become longer. That is, they start producing eggs when there are more hours of light per day. Typically, day-old chicks are kept on 23 to 24 hours of light per day for the first few days to make sure that they can find feed and water, especially water. After that period, you should reduce the number of hours of light per day. If you are raising the birds indoors, you can give them just 8 hours of light per day. If you are exposing them to outdoor conditions, you are limited by the number of hours of light per day in your area. When the pullets are ready to start laying, slowly increase the light exposure until they are exposed to about 14 hours of light per day. This exposure should stimulate the flock to come into lay. To keep the flock in lay year-round, you will need to maintain a schedule of at least 14 hours of light per day. You can increase the amount of light slowly to 16 hours per day late in the egg production cycle to help keep the flock in production [5].

Pullets grown as layers, if hatched between April and July in temperate climates, require no additional artificial light during the growing period as long as they are on the range or in windowed houses. The birds are maturing sexually as the days are growing shorter [3]. This decreasing day length is beneficial, from a physiological standpoint, as it slows ovarian development and allows the female to complete her skeletal growth before the rigors of egg production. Other than the light required during the initial part of the brooding period, natural light is sufficient for these birds [17]. Although existing commercial birds have great laying persistency, they can be affected by changes in the photoperiod and may adversely affect the laying [3]. It is usually enough to keep them on a stable photoperiod of 14 - 16 hours to maintain the birds in production. Nevertheless, birds use more energy for maintenance during the hours of light than during the hours of darkness [20]. Longer photoperiods tend to result in higher feed intake and egg size, but also there is increased mortality, thinner eggshells, and a slightly higher percentage of deformed eggs [20].

A study was conducted in Antananarivo, Madagascar using a total of 357 Isa Brown layers to assess the effects of lighting length on laying performance and on some egg characteristics in a family farm [21]. The birds, in their egg-producing phase (37 weeks old), were distributed at random into three lighting treatments: 12-hour natural daylight, used as control; 14-hour lighting length (natural daylight

+ artificial light), and 16-hour lighting length (natural + artificial light). The artificial lighting was supplied by 60-watt incandescent lamps placed within the treated lots. The result indicated that lighting length affects significantly layer weight and production performance. Layer weights tend to be lower with increasing lighting, but egg production increases with lighting length. Lighting length has no effect either on egg weight or egg volume, but it significantly affects the shell index and the egg's internal qualities [21]. Similarly, increasing the photoperiod (artificial lighting by 2 - 3 hrs) on laying hens indicated that, it can increase egg production by 20 - 30% [2,15]. The result further revealed that birds on 16-hour day-length treatment perform better in terms of laying rate, and feed conversion efficiency. Laying birds under natural daylight (12 hours) performs the least in both parameters. The details of the performance of Isa Brown's layers are summarized and presented in figure 4.

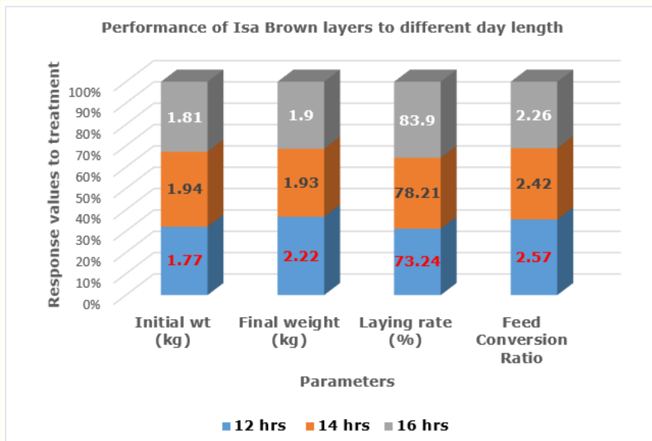

Figure 4: *Performance of isa brown layers to different day length.*

Source: [21].

Effects of light color on performance and immune response of chicken

Light color refers to wavelength and frequency and is important to avian reproduction because minimal light intensity is needed to elicit a photo-stimulatory response. Producers have clear requirements for both light color for brooding and light color for the laying flock. The color of the lighting also affects feed utilization and egg production. Generally, birds prefer to consume feed under white light because it helps them identify texture differences they cannot see under different colors [11]. In some cases, however, poultry producers may be prompted to use other light colors in order to alleviate a variety of production problems. Red light, for example, may be used for control of cannibalism, because birds cannot see the blood stimulant under red light. In other cases, blue or green lights may be used to keep birds calm by reducing hypothalamic gonadotropin production, and hence alleviate much of the losses caused by hyperactivity [11].

The feed intake response and egg production of layers reared under such light colors may not always be as good as with white light. Better results could, however, be obtained when interacting colors of light with other factors such as light intensity and feed color combined. In some studies, feed intake and egg production were improved under blue or green lights provided at high rather than low intensity [22]. In other studies, improvement was also obtained with red-dyed feed given under blue light, but no other combinations of light and feed colors have yet been examined [11].

In poultry, red light is vital for stimulating sexual maturity and egg production [23]. Birds exposed to red light versus blue, green, or white light consistently have higher egg production than the other color groups [23]. Red light can penetrate the skull to stimulate the extraretinal photoreceptors. Red light (around 650 nm) penetrates the skull and brain (hypothalamus) four to 50 times more efficiently than blue, green, and yellow-orange lights. The hypothalamus is important in regulating the production of hormones important for egg production [20].

Environmental factors in poultry housing, such as crowding, temperature, and lighting, influence the health and productivity of chickens [23]. Lighting is an important factor in regulating physiological and behavioral processes in chickens. Different wavelengths of light have been shown to affect growth rate and immune response in broiler chickens and egg quality in layer hens [23]. Laying hens exposed to red light have increased egg production and broilers exposed to blue and green light have increased weight gain [23].

An experiment was conducted using broiler chicks to evaluate the influence of light color on body weight gain and carcass weight. The results of the study indicated that light color influenced the live weight and carcass weights of broilers [24,25]. The result clearly revealed that broilers exposed to blue light significantly increased body weight throughout the experimental period (480 nm) whereas broilers exposed to green (560 nm) light gained the most weight on days 25 and 34. In this study, birds raised under blue and white light gained the most body weight on days 28 and 35 compared to birds raised under green and red light. Other studies have also reported increased body weight in broilers reared under blue and green monochromatic light [26]. Although [27] noted that broilers raised under green light were significantly heavier compared to other colors, broilers reared under blue light were the lightest of those evaluated. Conversely, broilers in this study attained the highest body weight in the blue light treatment group, and broilers in the green light treatment group gained the least amount of body weight. Feed Conversion Ratios (FCR) and carcass weights were positively correlated with live body weights for each treatment group [23]. In conclusion, the color of light increased the antibody response of broilers while not adversely affecting their performance. Broilers raised under red lighting had increased IgY titers than broilers raised under white, blue, or green light. Therefore, red light may be applied in poultry production systems to enhance the immune responsiveness of broilers to vaccination without adversely affecting performance [23]. The effect of light color on FCR and Carcass Weight (g) is summarized and presented in figure 5.

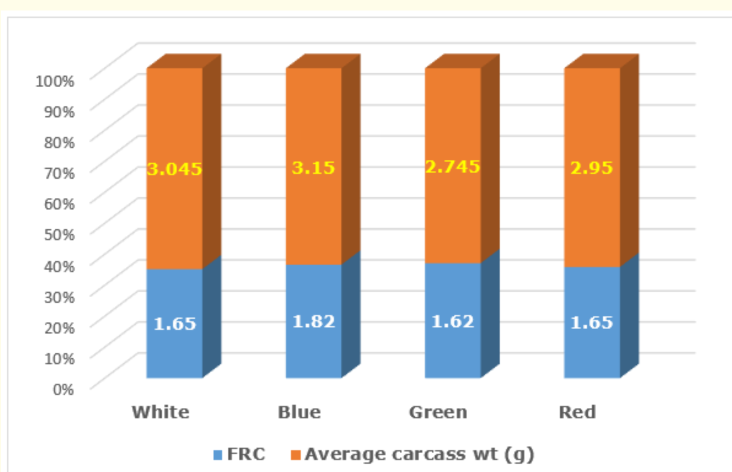

Figure 5: *Effect of light color on FCR and carcass weight (g)*

Source: [23].

Birds raised under blue light had the highest FCR (1.82) and carcass weight while birds raised under green light had the lowest FCR (1.62) and carcass weight. Birds raised under red and white light treatments had similar FCR (1.65) and carcass weights which implies, birds raised using green color are most economical [23].

The lighting experiment was conducted using twenty, Lohmann white layers 24 weeks of age, in their first laying year cycle, which were used in the experiment for a period of 5 weeks to see the effect of light color on egg laying performance and feed intake [10]. The experiment was conducted for five weeks in a deep litter housing system. For each treatment, five Lohmann White Layers were used, and data were collected for five weeks. The treatments were four different light colors; white (control), red, blue, and green using a bulb light of 60W on each experimental unit. The lighting program was in place with artificial lights, using continuous lighting of 12 hours and 12 hours of natural light, with no hours of darkness because winter days are shorter [10]. The green color had the lowest egg production 22.40 ± 1.325 and the White color had the highest egg production 38.20 ± 1.325. This means that white color can be used to maximize egg production. White and Red colors can be used in poultry provided with a proper lighting program. Pecking was observed under green color this might be due to stress associated with the continuous lighting. Continuous lighting is not always the best option because it increases electricity costs. Red color may not be used in egg production; however, it may be used as a complement to white light to improve egg production. Green and blue light may not be the best color in the production of eggs because these colors reduce ingestive activities and cause a decline in egg production [10]. The results are summarized and presented in figure 6 and 7.

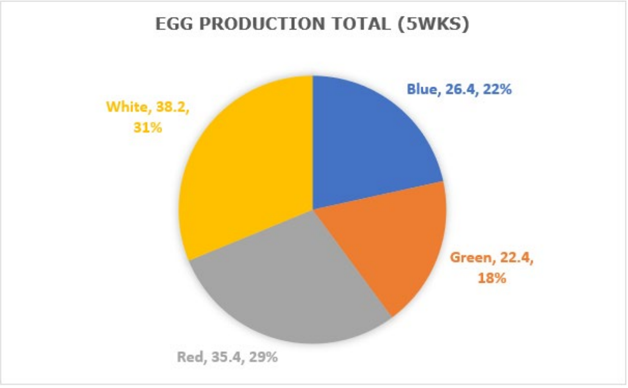

Figure 6: *Total eggs produced in 5 weeks using different light colors.*

Source: [10].

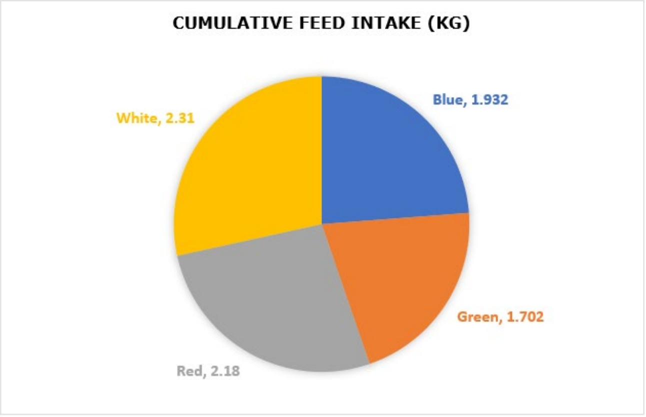

Figure 7: *Commutative feed intake (kg).*

Source: [10].

The result further revealed that there was an increased feed intake under the white color compared to the rest colors with a slight difference between white and red color. An increase in feed intake is associated with increased egg production. Continuous lighting may not be used as it can cause physiological stress that reduces feed intake and in turn, reduces egg production [10,28].

A study was conducted with the objective of comparing the performance of laying hens, the quality of air in poultry houses, and microbial contamination of eggshells in laying hens kept under blue, green, red, and yellow light color in enriched cages [29]. The daily photoperiod consisted of 15h light, with an intensity of 10 lx at bird head level [29]. The laying performance characteristics (hen-day egg production, mortality, and egg weight) were not affected by light color. Similarly, microbial contamination of the air was not significantly different related to the light color [29]. The details of the effects of light color are summarized and presented in figure 8.

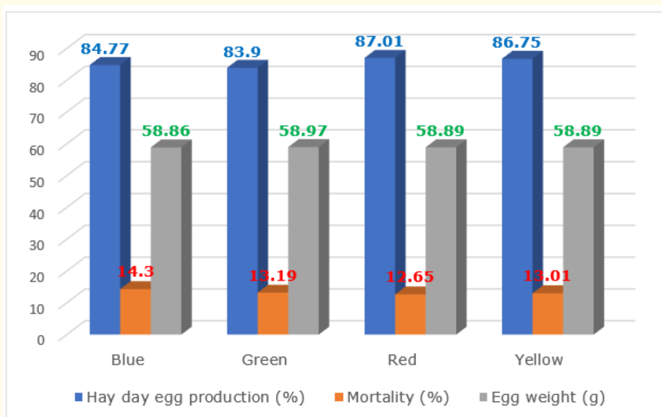

Figure 8: *Performance of laying hens under different light color.*

Source: [29].

A study was conducted to see whether monochromatic light affects the production performance, egg quality, and some plasma parameters of layers. In this study, white and green, fluorescent lamps were used to illuminate Brown-Nick hens for 8 weeks [30]. Light sources made uniform to a light intensity of 15 lx. Forty-seven-week-old layers were divided into 2 groups of similar mean weight comprising 16 birds each and housed in individual cages. A 16:8 hours light-dark photoperiod was employed. The results indicated that green light application did not have any significant effect on feed intake, feed conversion ratio (FCR), egg production, total number of eggs, total egg weight, average egg weight, a cholesterol level of egg yolk, and egg quality of laying hens. However, green light application affected egg yolk color values, but decreased serum albumin concentration. The results suggest that green light application may improve the yolk color of laying hens if the owner is interested in deep yolk color [30].

Effects of light intensity on the quality of eggs of commercial egg layers

It is usually recommended to start pullets with 20 to 22 hours of continuous and bright 30 to 50 lux (3 to 5-foot candles) light during the first week of age. Alternatively, an intermittent lighting program (4 hours of light followed by 2 hours of darkness) can be used during the first week of age. The dark period (or periods) serves as 'resting time' and helps strong chicks show the weak chicks how to find feed and water [5]. The light intensity should be 30 lux (3 foot-candles) during the first week of age, after which it can be reduced to 5 to 10 lux (0.5 to 1.0 foot-candles) in cages or to 15 lux (1.5 foot-candles) when grown on the floor. The higher light intensity for floor-grown birds will allow the birds enough light to navigate their environment. In cages, there should be 10 lux (1.0-foot candles) at the feeder and 5 lux (0.5-foot candles) inside the cage [5].

An experiment was conducted to examine the effects of light intensity (LI) from photo stimulation to 45 wk of age on egg production parameters and egg size characteristics and on ovarian and carcass morphology at sexual maturity and 45 wk of age in four-layer strains. Floor-housed pullets were raised in a light-tight facility from 1 day of age until housed in individually illuminated cages at 17 wk of age. Two white egg strains, ISA-White (ISA-W) and Shaver 2000 (S2000), and two Brown egg strains, ISA-Brown (ISA-B) and Shaver 579 (S579), were used. Pullets were randomly assigned to a processing group that was killed at sexual maturity (first oviposition) (Group 1) or kept for 45 wk (Group 2) [31]. Birds were photo stimulated at 18 wk of age using a Light Intensity (LI) of 1, 5, 50, or 500 lux (lx) (4 × 4 factorial design). One bird from group 1 and one from group 2 were caged together in individual cages (one brown and one white egg layer). Carcass and ovarian morphology data were examined as related to Strain, LI, or the interaction of strain and LI. The time from photo stimulation to sexual maturity did not differ due to LI but was shorter for brown egg strains (ISA-B = 19.9d, S579 = 20.2d) than for white egg strains (ISA-W = 26.6d, S2000 = 28.1d). Body weight at sexual maturity differed among all strains, with the white egg strains having the lowest BW. Ovary weight was the greatest in ISA-W birds, in which 8.0 large yellow follicles (LYF) were present compared to 6.8 in S2000 birds. The LI affected ovary development, as birds with the 1 lx exposure had lower ovary weights and fewer LYF than did 50 lx birds, suggesting that the 1 lx LI did not result in adequate photostimulation and sexual maturation. The threshold LI for a complete morphological response to photostimulation in this study was 5 lx. Strain differences in BW observed at sexual maturity continued to 45 wk of age. Light intensity affected 45 wk BW, with 5 lx LI birds weighing 7.2 and 8.7% more than the 50 and 500 lx birds, respectively. On an absolute basis, Brown egg stains carried significantly more breast muscle at 45 wk of age than did white egg strains. The fat pad was heavier on a relative basis for brown egg layers than white egg layers. The 1 lx hens had the lowest 45-wk ovary weights than the other three LI treatments [31]. The required light intensity of different age groups is summarized and presented in figure 9.

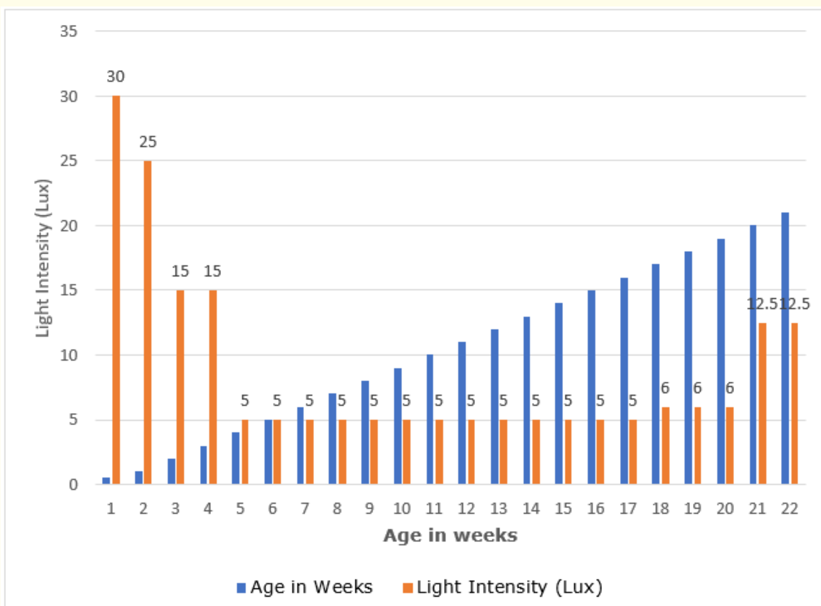

Figure 9: *Recommended Light Intensity for different age groups of birds.*

Source: [19].

Chickens are affected by the duration, intensity, and spectrum of light. Light can be utilized as a management tool to help optimize pullet growth, age of sexual maturity, egg weight, and egg production in laying hens in a variety of environments [19]. Intensity - Light intensity, measured in lux, or foot candles, is also important for poultry production. In general, light intensity below 5 lux is too dark to stimulate proper growth and production, while higher light intensity (above 50 lux) may cause nervousness and aberrant behavior. The standard recommendation for growing pullets is to brood for 2 to 3 weeks at 30 - 50 lux, and then dim to 10 - 15 lux until 14 weeks. Two weeks prior to the transfer, gradually increase the light intensity to match the levels in the layer house. Laying hens should be kept at an average of 30 lux at the level of the feed-through [32].

Once the birds are laying, it is not necessary to expose them to a high light intensity to keep them in production. In fact, an increase in intensity correlates negatively with feed intake and egg size. Similarly, the high light intensity can encourage certain undesirable behaviors such as feather pecking and cannibalism. Therefore, it is usually recommended to dim the intensity to around 10 lux at the feeder level after the peak of production. This should be done progressively and always checking that feed and water consumption and egg production remain unchanged. It should be remembered that the intensity is not homogeneous in a house, so the area with the lowest intensity should always be considered as the limit [33].

Effects of light on the reproductive performance of laying birds

The first important aspect of light is that it allows birds to be active and to find their food and water. But light has another very important effect on the pullet, or young female, in that it causes the production of follicle-stimulating hormone (FSH), which is necessary for the growth of the ovarian follicles, and the eventual production of an ovum (yolk).

Light is perceived by the bird primarily through the eye but can also pass through the skull. This light stimulus reaches the hypothalamus of the brain via the optic nerve. A message is then sent from the hypothalamus to the anterior lobe of the pituitary gland. The pituitary gland releases follicle-stimulating hormone (FSH), which travels via the bloodstream to the ovary. Under the influence of FSH, the ovarian follicles initiate growth and, in turn, produce the hormone Estrogen. Estrogen secretions from the developing follicles are responsible for the development and enlargement of the oviduct to allow for the passage of the yolk and the eventual formation of the egg. Estrogens also cause the spread of the pubic bones (through which the egg passes when laid) and enlargement of the vent necessary for oviposition, or expulsion (laying), of the egg [17].

Available light sources, their benefits, and shortcomings

Many different types of light sources are utilized in the poultry industry, ranging from open houses under the influence of the sun to the most technologically advanced layer houses with the newest equipment without exterior light influence. Understanding the spectral composition of different light sources is important for selection amongst multiple lighting types. According to different sources, including [3,17,18,32,34,35] incandescent lights are inexpensive, with good red spectrum output; excellent light distribution; and are quick to turn on but they have a very short lifespan, are prone to breakage; 90% of the energy used goes to heat rather than light, and do not comply with new energy efficiency standards. Compact Fluorescent lights are relatively energy efficient and relatively expensive. They have proven success in the layer and breeder industries, but they are prone to breakage with poor performance in cold weather. Bulbs require several minutes to reach maximum light intensity. Light-Emitting Diodes Light bulbs (LEDs) are currently the most efficient source of light since they use 90 percent less energy than standard lighting and last up to 25 times longer. LEDs light up quickly. They don't contain any toxic materials and they can operate in cold temperatures without flickering. LEDs are more expensive but have a much longer work life. LED lamps did not have any negative impact on the production and egg quality of the laying hens [36]. One 60-watt incandescent bulb with a reflector downward, 7 feet off the floor in the centre of a 12- x 12-foot pen, provides 2- to 3-foot candles (FC) of light, in the absence of any natural daylight. A 25-watt bulb in the same location should provide 0.5 fc of light. The conventional industry level for lighting is about 0.5 fc or less, like a moonlit night. However, most small-scale producers would prefer a somewhat higher level of light-from the equivalent of a 60- to a 75-watt bulb [17]. For small laying flocks, one 60-watt ceiling light (14-watt fluorescent or 9-watt LED) for every 200 square feet of floor space is adequate. For ceilings over ten feet, a 75-watt bulb (22-watt fluorescent or 13-watt LED) can be used [17].

Conclusion

The productive and reproductive performances of growing and laying chickens are affected by the genetic background of the birds, the environment where they are exposed, and the interaction effects of genotype by the environment. Among many environmental factors, the light intervention in terms of photoperiod, intensity, color, and source of light plays a major role in the performance of different age groups of chicken. Most research findings indicated that photoperiod does have a strong effect on the performance of laying as well as growing birds. Similarly, the intensity of light also plays a major role but, if the intensity of light is beyond the required level, then it will cause cannibalism, aggression, abnormal feed, and water intake, encourage birds to egg eating habits, enhance unrest and overall disturbance among the flocks. During the growth phase of the chicks, light hours start at 24 hours during the first week and decrease to nine hours per day by reducing light hours every week by 15 - 30 minutes till the age of six weeks and remain flat till the age of 17 weeks (nine hours per day). However, exposing birds to higher photoperiods beyond 17 hours per day after 17 weeks will result in prolapse of the reproductive tract, smaller egg size, diminished lifetime egg output, encourage birds for cannibalism, and increase overall costs of production by extra light cost. During the laying phase, increasing the photoperiod (artificial lighting by 2 - 4 hrs) beyond the natural day length on laying hens indicated that, it can increase egg production by 20 - 30%. The total light required by the high egg-producing laying strains ranges from 14 - 16 hours/day. The combination of quick step-down and quick step-up lighting is most effective for achieving the early onset of lay; slow step-down and slow step-up will delay it. If the producer wants early egg production, a high total egg number, and moderate egg weight, he should use the quick step-down/step-up variant. Birds exposed to red and white color lights do produce more eggs as compared to their counterparts exposed to blue and green lights. On the other hand, broilers exposed to blue light colors gained better body weight as compared to green light. Broilers exposed to red light had increased immunity titer levels as compared to broilers exposed to white, blue, and green light. The response of birds to light intensity indicated that the light intensity should be 30 lux (3 foot-candles) during the first week of age, after which it can be reduced to 5 to 10 lux (0.5 to 1.0 foot-candles) in cages or to 15 lux (1.5 foot-candles) when grown on the floor. The higher light intensity for floor-grown birds will allow the birds enough light to navigate their environment. In cages, there should be 10 lux (1.0-foot candles) at the feeder height, and 5 lux (0.5-foot candles) inside the cage. When the effect of the light source is evaluated, LED lamps are superior in terms of their technical performance, durability, and economics compared to incandescent, and fluorescent lamps even though the initial cost of LED lamps is on the higher side which will be eliminated after 2.25 years. Light-Emitting Diodes Light bulbs (LEDs) are currently the most efficient source of light since they use 90 percent less energy than standard lighting and last up to 25 times longer. LEDs don't contain any toxic materials and they can operate in cold temperatures without flickering. LED lamps did not have any negative impact on the production and egg quality of the laying hens.

Recommendations

- Artificial light is an effective means of controlling the performance of any flock. It will not, however, make high producers from inferior stock or take the place of correct feeding and management. Therefore, other management factors should go hand in hand with the lighting program.
- The use of different photoperiods, light intensities, and colors should go with the age categories. This implies we cannot apply similar light parameters to different age groups and breeds of chicken.
- We should maintain the regularity of lighting as per the recommendations and requirements.
- The so-called "step down procedure in the early days of a chick's life can be used to make the pullets more sensitive to light and never increase lighting length during the growing phase.
- Never decrease day length during the laying phase and supply 16 hours of day length during pick production.

- The combination of quick step-down and quick step-up lighting is most effective for achieving the early onset of lay; slow step-down and slow step-up will delay it. If the producer wants early egg production, a high total egg number, and moderate egg weight, he should use the quick step-down/step-up variant.
- The physical condition of fowls is the most important factor to be considered in lighting. No attempt should be made to force sick, thin, or immature fowls into production under lights, and fowls that are being lighted should always be fed to maintain their body weight.
- Red and white color lights are important to increase egg production whereas blue light is important in broiler production to increase body weight.
- The Artificial light supplementation of 2-3 hours is recommended during the early morning instead of the evening.
- Light-Emitting Diodes Light bulbs (LEDs) are currently the most efficient source of light since they use 90 percent less energy than standard lighting and last up to 25 times longer. LEDs light up quickly. They don't contain any toxic materials and they can operate in cold temperatures without flickering.
- Every poultry producer, therefore, should follow the producers' specific light recommendations for the profitability of their business.

Conflict of Interest

The authors declare that there are no conflicts of interest related to this study.

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