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Relationship between chicken and light: A review

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Abstract
Lighting is the most crucial external factor of poultry production. In terms of intensity, colour, duration and sources, lights are key component in physiological and behavioral activities of chicken. It impacts on production, reproduction, maturation, behaviour and health of chicken. Various colors of light have significant effect on growth performance, sexual development and maturation in both (broiler and layer), in which most of the recent studies indicated that green and blue light or the combination of green-blue light gave positive results on body weight and immune system, whereas, red light increased the activities and aggressive behavior of birds. For chicken, 20 lux light intensity in recommended during chick period and 3-5 lux intensity advocated during grow-out period. Intermittent lightening (4 hrs. on, 2 hrs. off) comparatively more suitable and recommended than the constant light for broiler and during chick period and also day light duration is sufficient for growth. Light duration of 14 hrs. is recommended during grower period and increase 30-35 min light weekly until light duration reach up to 16 hr. for layer. In recent decades, LED lighting, in terms of colour diversity and homogeneous distribution, has proved efficient in improving the performance of chickens as compared to other sources. When managing a healthy and productive flock, getting the right lighting conditions could be more important than other tools use in poultry farming.

Keywords: Light, broiler, layer, colour, duration, intensity, Incandescent, LED and CFL

Introduction

Our life is significantly impacted by light. It guides and affects us in many ways, internally and externally too. Internally, it affects our mind and a wide variety of physiological processes within our body. Eyes are undeniably one of our most important organs. Light (visible light) is electromagnetic radiation within the portion of the electromagnetic spectrum that is perceived by the human eye or any eye of the livestock or bird (CIE, 1987) [12]. Visible light is having wavelengths in the range of 400 (infrared 430 THz) to 700 (ultraviolet-750 THz) nanometers (nm). Light is an important aspect of an animal's environment and have three major functions: 1. to facilitate sight, 2. to stimulate internal cycles due to day-length changes and 3. to initiate hormone release.

Lighting is on eof the powerful and critical encviornmental factors which control vision, thereby many physiologucxal and behavioral processes in the birds (Sirohi *et al.*, 2020) [51].

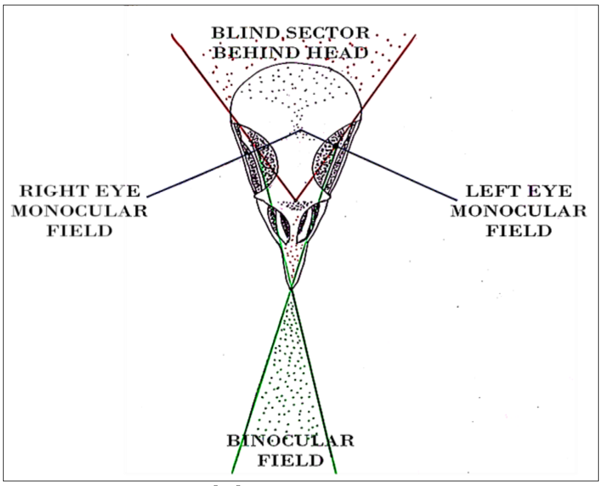
Avian species as well as mammalian species respond to light energy in a variety of ways, including growth, reproductive and productive performance. Since the beginning of intensive poultry production, light has been an important management tool to regulate poultry production, health and welfare. Light also stimulates secretary patterns of hormones that have a role in growth, maturation, reproduction, visual acuity, colour discrimination, establish rhythmicity and synchronize many essential functions, including body temperature and various metabolic steps that enhance feeding and digestion (Olanrewaju *et al.*, 2016) [34].

Light has an impact on the pineal gland; it also helps in synchronization of circadian rhythm and inhibiting melatonin release. The further circadian rhythm supports the bird to optimize their metabolism, physiology and behavioral pattern (Schwan-Lardner *et al.*, 2016) [48].

Presently, a number of lighting programmes (wavelength, intensity and duration) and devices are utilized by the poultry producers. According to Parvin *et al.* (2014) [38], the emphasis of poultry lighting has been placed on various light Colors (e.g., blue, green, red, and white) and lighting sources (e.g., incandescent, fluorescent and LED lights). Several researchers have demonstrated that red light have an accelerating effect on sexual development and maturity of poultry (Baxter *et al.*, 2014; Yang *et al.*, 2016) [5, 56]. In contrast, blue lights were found to be more associated with improving growth, calming the birds, and enhancing the immune response, although the underlying mechanisms have not been clearly delineated (Xin *et al.*, 2008; Sultana *et al.*, 2013) [52, 55]. The potential use of photoperiod for better production and management is gaining interest day by day. This review briefly describes how light influences the production and reproduction traits of chicken and also provides a direction to improve the production and the economy.

Physiology and anatomy of poultry eye and light

The positioning of chicken's eyes is on both sides of the head which are responsible for binocular visions and monocular vision (Fig. 1). There are two types of light-receiving cells in the retina. The first type is the rod cells, which are heavily sensitive to light and provide the ability to see in the night vision (can't distinguish the colors). The second type is the cone cells that are responsible for daylight or colour vision. The number of rod cells is more than cone cells. Rod cells are active at less than 4 candle/m^2 light intensity. However, cone cells are activated at higher (4-44 candle/m^2) intensity. Chickens' eyes have another type of cone cell, with a maximum sensitivity of 415 nm which means that the chickens are able to see in the Ultraviolet-A (Olanrewaju *et al.*, 2006; Signor *et al.*, 2013) [35, 50].



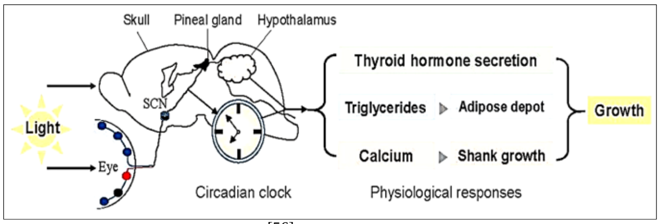
(**Source:** Watson, 2017) [54]

Fig 1: Binocular and monocular vision of chicken eye

Avian Vision

The chicken (*Gallus gallus*) has tetrachromatic colour vision mediated by four types of single cone which are maximally responsive to violet, blue, green and red light (Bowmaker *et al.*, 1977) [7]. Campenhausen and Kirschfeld (1998) [8] found that double cones consist of pairs which act as a single functional unit and are thought to mediate luminance detection that is used for motion perception. In contrast, placental mammals have lack of double cones and therefore, use a single set of cones for both functional purposes (Osorio and Vorobyev, 2005) [36].

Vision eye receives light stimulus and transforms it into a nerve impulse which runs along the optic nerve reaching the visual cortex and gives rise to visual sensation. Poultry has four types of retinal cone photoreceptors in the eyes. These photoreceptors produce the perception of light colours by receiving lights at the peak sensitivities of approximately 415, 450, 550, and 700 nm which are directly related to poultry activities and growth (Osorio and Vorobyev, 2008) [37]. Besides the retinal cone photoreceptors in the eyes, poultry can also perceive light via extra-retinal photoreceptors in the brain (*i.e.*, pineal gland and hypothalamic gland) (Mobarkey *et al.*, 2010) [28]. Light stimuli perceived by the extra-retinal photoreceptors can impact sexual development and reproductive traits of poultry. However, the extra-retinal photoreceptors (Fig. 2) can only be activated by long-wavelength radiation that can penetrate the skull and deep tissue of the head (Lewis and Morris, 2000) [25].



(Source: Yang *et al.*, 2016) [56]

Fig 2: Physiology of light in chicken

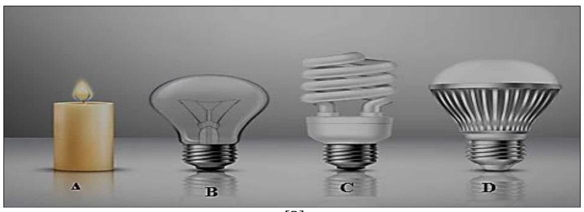
Effects of light on chicken

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 (Rault *et al.*, 2017) [42]. Management of light has emerged as one of the crucial managemental tools for poultry production. Several researchers found that the influence of light results from a combination of light sources, light intensity, light colour, and the photoperiod regimen (Olanrewaju *et al.*, 2006; Cao *et al.*, 2012) [35, 9]. According to properties of lights which affecting the growth, maturation, health, production, reproduction and welfare in chickens, light can be classified into four groups:

1. Sources of light,
2. Intensity in terms of illumination (Intensity of light),
3. Colour of light and
4. Duration of light

1. Sources of light

The Sun is natural source of light on Earth. Historically, another important source of light for humans has been fire, from ancient campfires to modern kerosene lamps. Due to revolution in electrical field, various artificial lights were developed by scientists. There are dozens of sources, with a few common in household applications and others more suitable for industrial uses. The four most common light sources (Fig. 3) other than natural light are Candle/lamp, Incandescent lamp, Compact fluorescent lamp (CFL), Fluorescent tube and Light Emitting Diode (LED).



(**Source**: Anonymous, 2020) [3]

Fig. 3: Artificial light sources (A- Candle, B- Incandescent, C- CFL and D- LED)

Table 1: Comparisons of different light sources

Sr. No.	Types of light	Longevity (Hours)	Illumination (Lumen/watt)	Cost	Electricity bill	Remarks
1.	Day light		120000 at noon	-	-	-
2.	Incandescent lamp (INC)	750-1000	12.56	low	high	Needs Reflector, like natural light, uses more energy, less life and less efficiency
3.	Compact fluorescent lamp (CFL)	8000-20000	46-80	Medium	Medium	4 times more efficient than INC and use less energy and works for longer life than above
4.	Florescent tube	24000-36000	70-104	Medium	Medium	
5	Light emitting diode (LED)	35000-50000	80-160	high	low	High level of brightness and power with high efficiency Use of low-voltage currents and low heat emission High reliability (physical stability) with no UV radiation Long lifetime and easily programmed and controlled as part of an electronic array (for example in computer and TV displays)

(**Source:** Ankuya *et al.*, 2022)

Currently, owing to the high energy efficiency, long working life, availability in different peak wavelengths, low electricity consumption, and low rearing cost (Sultana *et al.*, 2013a, b; Hassan *et al.*, 2014; Liu *et al.*, 2017) [52, 19,], light emitting diodes (LEDs) are gradually becoming a substitute for conventional incandescent and fluorescent lights for lighting in poultry houses (Yang *et al.*, 2016; Li *et al.*, 2019) [56, 26]. Hajra *et al.* (2009) [17] concluded that fluorescent light was better than incandescent light for commercial broiler production. However, birds under fluorescent light group had adjusted themselves and were observed to be undisturbed during light on or off, mandatory for providing 18L:6D photo-schedule. Incidently, less activity contributed to utilize their energy in productive purpose and to perform better than the birds of incandescent light group (Hajra *et al.*, 2011) [18].

2. Intensity of Light

Illumination on a surface is measured in foot-candles (fc). A foot candle is defined as the intensity of light striking each and every point on a segment of the inside surface of an imaginary one-foot radius sphere with a one candlepower source at the center. Thus, one-foot candle equals one lumen per square foot (1 fc =1 lumen=10.76 lux). Light intensity has a strong impact on broiler behavior. In general, brighter light (increase intensity) will result in increased activity, while, decreased intensities (dim light) are effective in controlling aggressive acts that can cause cannibalism. Modern electronic systems are commonly used by the producers to increase light intensity for short periods during grow-out to increase exercise and thereby reduce skeletal and metabolic disorders (Anonymous, 2022) [4].

2.1 Effect of light intensity for broilers

In the case of broilers, during the early part of life (1-7th day during brooding period) a minimum light intensity of 20 lux is used. Following the early period, the restriction of both light intensity and duration is a common practice. The intensity should be 3 to 5 lux and duration of 2 to 6 hours per day for the rest of the grow-out period. Several researchers reported improved body weight (BW), feed intake and feed-gain ratio under 1 and 5 lux, in contrast to birds given much brighter (40 and 150 lux) light (Charles *et al.*, 1992; Lien *et al.*, 2008) [11, 27]. Very bright light (100 and 150 lux) may stimulate the activity of broilers to the extent that they used more energy for maintenance and physical activities instead of growth. Further, some researchers (Deep *et al.*, 2010; Zhao *et al.*, 2018) [15, 59] have shown that, light intensity had no effect on overall broiler live performance, indicated by insignificant differences in average daily gain (ADG), body weight (BW), feed intake (FI), feed-gain ratio (F: G) and mortality rate in case of young broiler chicken. The difference in result might be due to variation in strains, climate and geographical location of the experimental sites.

Most carcass characteristics were found independent upon light intensity, but exceptions are thighs, drums, and wing yield as a percentage of live weight. Carcass yield decreases linearly with increasing the light intensity from 1 to 40 lux. Dim light (5 lux) resulted in increased fat and decreased protein levels of the carcass and author postulated that it might be due to decreased activity of birds kept in dim light (Charles *et al.*, 1992) [11]. Adequate light intensity is required to stimulate receptors responsible for gonadotropin-releasing hormone (GnRH) release in the hypothalamus because receptors are sensitive to light directly passing through the skull instead of the perception of light by eyes (Robinson *et al.*, 2003) [44]. Dim light (<5 lux) may not be able to penetrate the skull; thus, unable or less likely to excite receptors to release GnRH (Morgan *et al.*, 1995) [29]. Thus for broiler, during initial phase of life (chick period), 20 lux light intensity is recommended and after chick period, 3-5 lux light intensity is advocated.

2.2 Effect of light intensity for layers

Light intensity should be sufficient to allow young birds to find feed and water in the first few days after placement in house. The chicks should be provided 23 hours of light and 1 hour of dark for the first 2 days after placement. Further, Light intensity must be uniformly distributed throughout the brooding area. A light intensity of 80-100 lux (7-9 fc) must be provided in the brooding area to promote feed and water intake (Anonymous, 2018).

An intermittent lighting program (4 hour light: 2 hour dark or 5 hour light: 3 hour dark) is preferred during the first week. If farm is not adopting an intermittent lighting program from 0-7 days, then use 22 hours of light from 0-3 days and 21 hours of light from 4-7 days. But never give continuous 24 hours of light to the chicks to avoid the panic in the event of black-out, after that, gradual decrease in the light during 2-16 weeks of age with 12 hours of light in a day. From 17 weeks onward gradually increase in light up to 30 weeks of age approximately 15-30 minutes per week, reaching 16 hours maximum in a day, to rest of life (Hy-line, 2018) [21]. Bright light (30-50 lux) light intensity is suggested during 0-7 weeks for helps to chicks quickly find feed and water and adapt to the new environment. During 7-14 weeks, 5-15 lux is recommended then after 20-30 lux light intensity advisable during grow-out period (Hy-line, 2018) [21].

3. Colour of the light

Colour is also one of the major aspects of light. Chickens are possessing normal vertebrate trichromatic vision and trained to discriminate colours (Bell and Freeman, 1971) [6]. It is to be expected that colour, which is essentially a change in intensity at certain wavelengths, would also affect growth and behavior (Morris, 1968) [30].

Three types of pigment are found in the human retina (red, green and blue), whereas, chicken retina has two types: rhodopsin and iodopsin (Yoshizawa *et al.*, 1992) [57]. In recently advanced poultry farming management system, artificial lights are generally used, thus selection of light in the farm is crucial. In birds, radiation can pass through the hypothalamic extra retinal photoreceptors of poultry and stimulate the hypothalamus-pituitary growth axis to release the related hormones (Lewis and Morris, 2000) [25], thereby having an accelerating effect on activity stimulation, sexual development and the maturity of poultry (Baxter *et al.*, 2014; Li *et al.*, 2019) [5, 26]. Further, short-wavelength (purple, blue, and green) light appear to inhibit reproductive activity in birds, as well as it inhibits iodopsin, which also affects the sexual development (Crescitelli *et al.*, 1964) [14].

Prayitno *et al.* (1997) [40] reported that there were no differences in behavior under red and white light conditions, whereas, blue and green lights have a calming effect on birds, while birds reared in red light are more active and show enhanced walking, flying, head movement, litter scratching, body shaking, wing flapping, wing/leg stretching, feather pecking, aggressiveness and cannibalism (Khaliq *et al.*, 2018) [23]. Frequency of eating, intense sleeping, sitting and idling behaviors are more in blue light, while, green light promotes preening, dust bathing and drinking (Hesham *et al.*, 2018) [20]. Rozenboim *et al.* (2004) [46] suggested that blue-green light stimulates growth in chickens, while orange-red stimulates reproduction.

Broilers under blue or green light become significantly heavier than those reared under red or white light. Green light accelerates muscle growth and stimulates growth at an early age, whereas, blue light stimulates growth in older birds (Rozenboim *et al.*, 1999; Rozenboim *et al.*, 2004; Hesham *et al.*, 2018) [47, 46, 20].

Immune function of poultry is also affected by light colour (Cao *et al.*, 2008) [10]. Blue colour promotes the calming effect in bird (Prayitno *et al.*, 1997) [40] which has been shown to enhance the immune response (Zhang *et al.*, 2014) [58]. Hence, blue light may play a vital role in alleviating the stress response and improve the immune level in poultry (Xie *et al.*, 2008) [55]. Light colour can affect the immune performance of chickens in the early part of the rearing period and may subsequently influence the mortality of layers during the laying period. In addition, the photoreceptors in the hypothalamus of the poultry are more sensitive to blue and green light than red light (Osorio and Vorobyev, 2008) [37]. Short-wavelength (blue and green) light helped the chickens to remain calm and quiet and reduced the response to ultimately environment, promoting the immune performance of the pullets. Scott and Siopes (1994) [49] observed that the colour of light might affect the immune function indirectly via hormonal intermediates, such as affecting the melatonin or prolactin levels. However, the mechanism by which blue and green light affects the immune performance of laying hens remains to be studied.

4. Effect of duration of light

Lighting duration is the second major tool of light that alters broiler performance. During the brooding period, lightening duration is generally maximized to allow chicks to access feeding and watering equipments. In practice, continuous lightening is not recommended, but may be left on for 23 hours a day in the first 3-7 days with one hour of darkness to avoid in panic in the event of complete black-out. Alternatively, intermittent lightening (4 hrs on, 2 hrs off) may be used for layers chicks during the first week after placement. After the brooding period, light period is adjusted to maximize the pullet growth and optimize the sexual maturity. There is slow step-down of lightening from 0-8 weeks, until lights are on for 10 hours of the day. After which there are gradual increase in light from 16-30 weeks of age. A slower step-down of light hours from 0-12 weeks can be used to prevent early sexual maturity, maximize pullet growth and promotes early egg size (Kumar *et al.*, 2022) [24].

4.1 Effect of light duration on broilers

Cherry and Barwick (1962) reported that broilers perform better under the continuous lighting. Further, Morris (1968) [30] revealed that continuous light or 23hr light: 1hr dark is generally used in commercial production, which allows for maximum growth rate in broilers.

Lightening length is generally dependent upon the age of chickens concerned and type of housing. However, broilers need to be provided four (04) hour for sleep, but they may require higher lighting hours at certain points of growing period (Renden *et al.*, 1996) [43]. Several researchers have compared the effects of constant lightening (CL) and intermittent lightening (INL) on broilers, and found that INL can improve birds' growth performance as well as reduce fast growth-related diseases, such as leg problems, sudden death syndrome, ascites and thereby improve livability (Classen *et al.*, 1991; Rahimi *et al.*, 2005) [13, 41]. Pal *et al.* (2019) suggested a sample lighting programme recommended for broilers (Table. 2), but even though research and discussion remain continue in an attempt to define the optimal photoperiodic regime suitable for broilers.

Table 2: Sample lighting Programme recommended for broilers

Age (days)	Light Intensity (Lux)	Photoperiod (L=Light, D= Dark)
0-7	20	23.0L:1.0D
8-14	5	16.0L:8.0D
15-21	5	16.0L:3. 0D:2L.3D
22-28	5	16.0L:2.0D:4.0L:2.0D
29-35	5	16.0L:1.0D:6.0L:1.0D
26-49	5	23.0L:1.0D

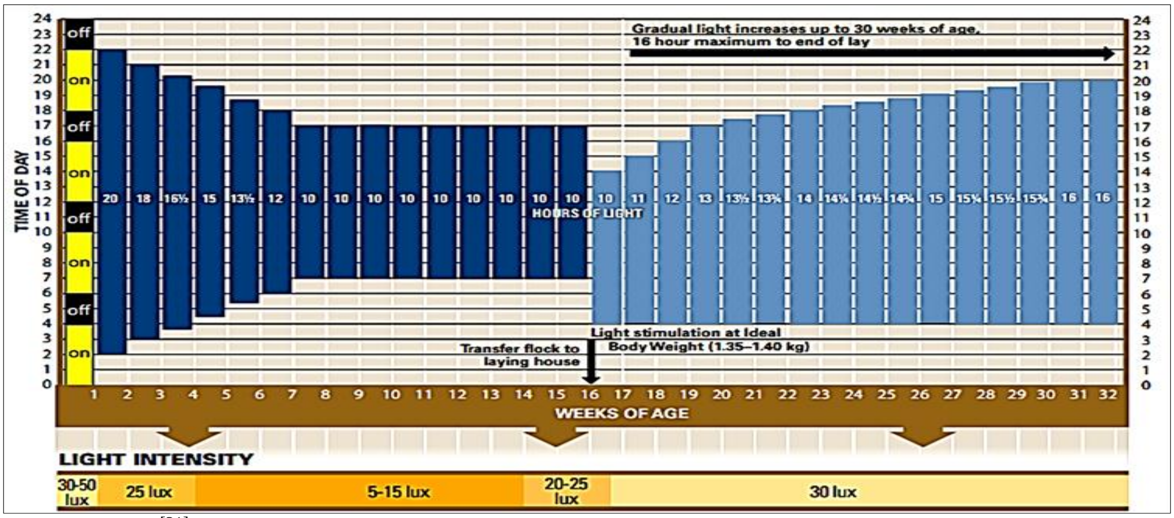
(Source: Pal *et al.*, 2019)

4.2 Effect of light duration for layers

The 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 optic nerve for the release of follicle stimulating hormone (FSH) and luteinizing hormone (LH). Light energy also penetrates through the skull, skin and feathers. FSH increases the growth of the ovarian follicles. Upon reaching up to the maturity, the ovum is released by the action of LH. For maximum egg production, 16 hours light is needed during peak egg production period. Reducing photoperiod during laying period seriously affects the egg production. The artificial light can be given either in the morning, evening or both morning and evening (Hy-line, 2018) [21].

Two intermittent programs have specific designations: the Cornell program and the biomittent program. Tienhoven and Ostrander (1976) [53] at Cornell University developed the Cornell program, in which 2 hours of light (2L), 4 hours of dark (4D), 8 hours of light (8L) and 10 hours of dark (10D) are supplied (2L:4D: 8L:10D).

The biomittent lighting program consists of fractioning the time of alternate light and dark cycles (25%L: 75%D). According to Morris and Butler (1995) [31], the objectives of the programs were to increase egg size and to improve eggshell quality. In the biomittent program, only 15 min of light are supplied per hour during the stimulation period, which may be interesting as it reduces lighting in 75% and improves feed efficiency in 5-7%. However, studies have shown that egg size was reduced in 0.5-1% when this program was applied (Rowland, 1985) [45].



(Hyaline, 2018) [21]

Fig 4: Lighting programme for layers

Morris *et al.* (1988) [33] compared both the programmes and revealed that the Cornell program reduces electric energy consumption and feed intake and promotes higher egg production. On the other hand, despite reducing feed intake, egg size and weight were also reduced when the biomittent program was applied before hens were 22 weeks old (Morris *et al.*, 1990) [32]. Hence, two important points may be concluded regarding lightening, first the length of the light day should never increase for growing pullets and second, the length of the light day should never decrease for laying pullets.

5. Arrangement of Bulbs in Poultry Housing

- During chick phase, the heat and light source should be olaced in the centre of the brooder guard. So that, the maximum illumination (Fig. 5) and light source/heat power is spreaded over throughout the brooder guard (French, 1981) [16].
- Zulcovich (2005) [60] demonstrated the arrangement if bulbs in poukltry housing (Fig. 6). There should be spacing of 8 feet betweentwo lamps lengthwise and 7 feet bridthwise.The same spacing for hanging lamps as well as ceiling lighting source.
- Kumar *et al.* (2022) [24] summarized the arrangement of bulbs in poultry housing as below:
- The lamps should be placed at adequate area so that the maximum illumination value is spread over the largest area. This all depends upon the physical dimensions and equipment in poultry building/house.

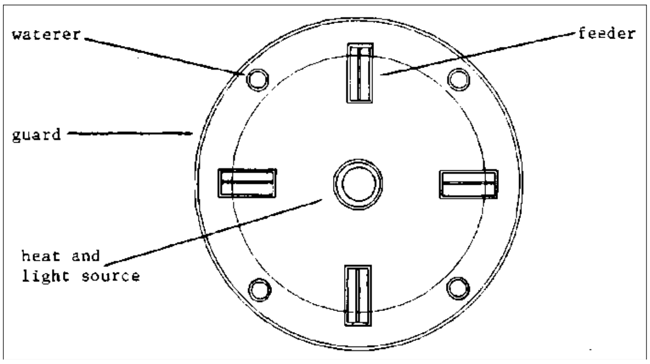


Fig 5: Arrangement of light bulbs in brooder guard Source: French, 1981) [16]

- One-Watt light intensity per 1 to 1.5 birds or per 0.28 sq.m. and 40-Watt bulb for 9.3m^2 floor space is recommended.
- Bulb height: 2m above the floor and distance between the two bulbs are 2.5m to 3m is recommended.
- Lower lamp is kept 1.8-2m away from the ground and the upper lamp is kept 0.2-0.4m away from the top of the chicken coop.
- The distance between bulbs should be 1½ times the distance from the bulb to the bird level.
- The distance from the bulbs to the outer edges of the house should be only ½ the distance between bulbs.
- In cage system, the bulbs should be placed in such a way that their rays fall on the feed and on the birds.

- Clean reflectors increase the light intensity at bird level by 50%, compared with no reflector.
- Avoid cone shape reflectors since they confine the light rays to limited area. Better to use flat type reflector with rounded edge.
- In case of deep litter system, the bulb is to be placed at 7-8' height, whereas, in cage house, keep in aisle.
- Avoid hanging bulbs by a cord in open houses.

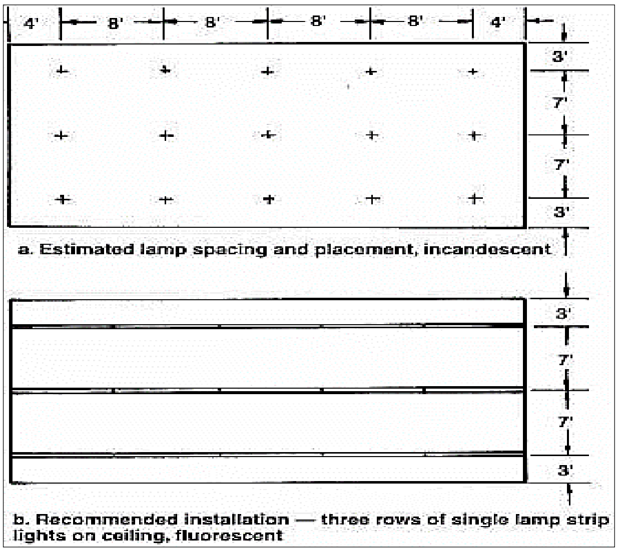


Fig 6: Arrangement of bulb in poultry housing (Source: Zulovich, 2005) [60]

6. Cleanliness of bulb and reflectors

Cleanliness of the bulb with a reflector is also important to produce calculated quantity of light. Clean reflectors, on most occasions, improve the light efficiency by about 50 percent since they reflect the light that would have been absorbed by the ceiling. It is preferable to use flat-type reflectors rather than cone-type, since the latter confines light to too small an area. Incandescent bulb will lose up to 20% of their original light output during their rated life (Darre and Rock, 1995). Very dirty bulbs emit about 1/3 less light than clean bulbs. Light bulbs should be cleaned once in two weeks (Table: 1). For any bulb, cleaning through a dry cloth or duster is the safest bet to avoid getting water in any electrical workings in the bulb's fixture. Clean the bulb with 50/50 mix of 70% isopropyl alcohol and RO (Reverse Osmosis) water or bottled water (Anonymous. 2019) [2].

Table 3: Effect of cleanliness of Bulb and Reflector under light intensity of INC bulbs

Bulb and reflector	Equivalent light-intensity
Clean bulb with Clean reflector	100 Watt bulb
Clean bulb with No reflector	60 Watt bulb
Dirty bulb with Dirty reflector	60 Watt bulb
Dirty bulb with No reflector	40 Watt bulb

Conclusion

Light is most important external factor for livestock and poultry production and it has vital role in poultry physiology as well as production. Intensity, colour, duration and sources are key component of lights which regulates the physiological and behavioural activities of chicken. For broilers during chick period (0-7 days) 20 lux and after that 3-5 lux light intensity is recommended. It is advisable that intermittent light (04 hr light: 02 hr darkness) improve better growth performance than constant light (23 hr light: 1 hr darkness). For layers 20 lux light for early life and 5 lux for grow-out period is recommended. It may be concluded that length of the light day should never increase for growing pullets and the length of the light day should never decrease for laying pullets. Various colours of light have different actions on the chicken. Practically, combinations of blue and green light are recommended for better performance in chicken. Further, there is need to study the mechanism by which light affects the immune performance of chickens.

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