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Lighting, density, and dietary strategies to improve poultry behavior, health, and production

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Abstract Poultry production is the most rapidly expanding agricultural industry. Consumer awareness of animal welfare has grown in recent years, and as a result, consideration for higher-quality meat production has increased. Environmental changes impact agricultural activity, including poultry production. These changes have raised serious worries that will severely impact poultry health and productivity due to climate change. In light of current environmental changes, determining the ideal environmental conditions for animals is a difficult challenge for researchers and breeders. When investigating the best environmental conditions for better poultry rearing and production, we must consider lighting, density, and dietary factors. These factors have separate and interactive effects on birds' behavior and performance. Understanding animal behavior is a key criterion for assessing animal welfare. It can assist breeders in better managing farm animals by reflecting the adaptability of the animal body to the surrounding environmental conditions. However, the optimal light quality and quantity, density, and feeding levels for poultry farming, particularly for chickens, are still a source of considerable debate among researchers and breeders. Therefore, this review discussed the current practical strategies for improving poultry behavior, health, and production through lighting, density, and feeding factors.

Keywords: animal husbandry, bird, feeding, lighting color, welfare

1. Introduction

Environmental changes impact agricultural activity, including poultry production. These changes have raised serious worries that will severely impact poultry health and productivity due to the current climate change. Poultry production is the most rapidly expanding agricultural industry. It is generally categorized into meat and egg products (Ren et al 2020). Based on FAO's reports, worldwide meat demand is expected to rise by 40% by 2030, compared to average 2005-2007 levels, reaching over 400 million tonnes, to meet the world's growing population and increased meat consumption. According to recent OECD-FAO statistics, global meat output (poultry, beef, sheep, among others) would increase by approximately 35% by 2030, with demand for poultry meat increasing by 50%, the majority coming from developing countries.

Poultry production can be accelerated to understand better appropriate circumstances for avian behavior, health, and welfare. Consumer awareness of avian health and welfare has grown in recent years, and as a result, consideration for higher-quality meat production has increased. Concerns about animal welfare continue to be an interesting issue for researchers, breeders, and animal rights organizations. On the other hand, breeders must adopt innovative technologies that can help them to increase production at a lower cost and with fewer negative environmental consequences to meet that demand. Most of these technologies aim to improve traditional inputs, including lighting, density, and feeding.

Determining the ideal environmental conditions for animals, in light of current environmental changes, is a difficult challenge for researchers and breeders. For animals to express their maximum genetic potential, they must be exposed to ideal environmental conditions. Recommendations for optimal environmental factors (light, temperature, humidity, ventilation, among others) are critical to increasing profitability and decreasing physiological stress in birds. When investigating the ideal environmental conditions for better poultry rearing, we must consider dietary, density, and lighting factors. Lighting, density, and feeding all have separate and interactive effects on bird's performance (Figure 1). However, the optimal light quality and quantity for poultry farming, as well as density and feeding levels, particularly for chickens, are still a source of considerable debate among researchers and breeders. Thus, this review presents a comprehensive overview of current practical strategies for improving poultry behavior, health, and production through lighting, density, and feeding factors.

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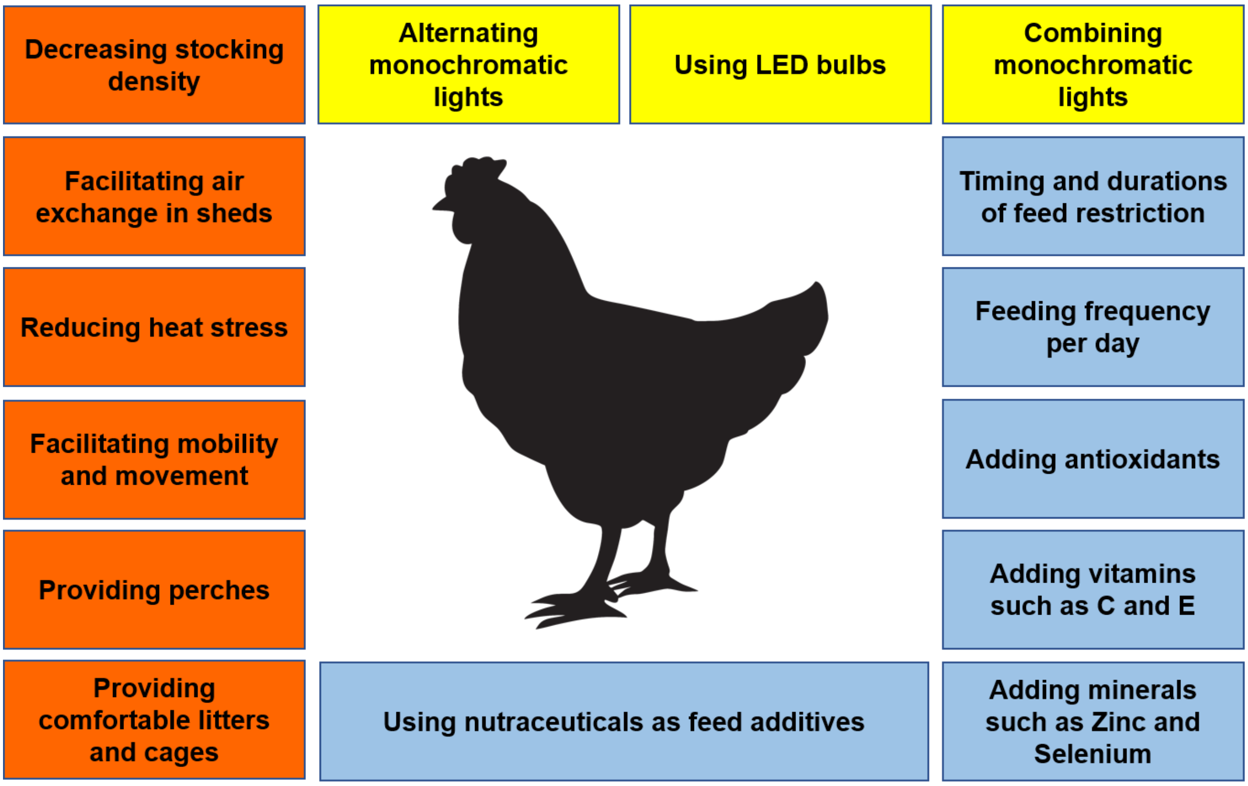

Figure 1 Practical husbandry strategies to improve poultry behavior, health, and production.

2. Lighting strategies to improve poultry behavior, health, and production

Lighting is an essential environmental component in poultry housing systems. It is a powerful exogenous factor with direct and indirect impacts on poultry raising and productivity (Table 1). It influences poultry growth, development, and productive performance (Lewis and Morris 1998; Soliman and El-Sabrout 2020). Additionally, it is an important microclimate factor that significantly impacts poultry behavioral activities (walking, foraging, drinking, among others), physiological functioning (digestive, reproduction, among others), and immunological response (health) (Yang et al 2016; Soliman and El-Sabrout 2020). It has also been found that light is very critical in the whole chick's life, from incubation through marketing. Good light programming enhances birds' behavior, health, feed intake, productivity (body weight), and well-being, resulting in more profitable production.

Light penetrates through the eyes and the top of the skull in birds via the pineal gland and the pituitary gland next to the hypothalamus (Soliman and El-Sabrout 2020) (Figure 2). In comparison to humans, birds have superior visual abilities, including the ability to perceive a wide range of colors (Prescott et al 2003). Bird visible light has a wavelength range of 380 nm to 740 nm, falling between invisible infrared (longer wavelengths) and invisible ultraviolet (shorter wavelengths) light rays, according to Parvin et al (2014). According to Lewis and Gous (2009), birds can perceive ultraviolet light below 400 nm in addition to the human range (400-750 nm). Lewis and Morris (2006) reported three primary elements influencing poultry's vision: retinal, pineal gland, and hypothalamus characteristics. The retina guarantees that birds can clearly see their surroundings and behave appropriately, as well as that the effects of light are directed toward growth and behavior (Wilson and Lindstrom 2011).

The bird's circadian rhythm serves in the optimization of its metabolism, physiology, and behavioral pattern. Light assists the bird in establishing rhythmicity and synchronizing numerous vital functions, such as body temperature and various metabolic steps that improve feeding and digestion (Pal et al 2019). Light also promotes the secretion of hormones involved in the development, maturation, and reproduction (Olanrewaju et al 2016; Yang et al 2016). It mainly affects the pineal gland, aiding in synchronizing circadian rhythms and limiting melatonin release (Deep et al 2012).

Since 1950, house lighting systems have promoted bird growth and development (Cao et al 2012). Artificial lighting has been utilized in poultry farming to influence physiological responses and metabolism, and increase productivity. Light wavelength (color), intensity (brightness), and lighting duration (photoperiod) are the three primary components of artificial lighting (Wei et al 2020; Soliman and El-Sabrout 2020). The effect of light is caused by a combination of light sources, intensity, color, and photoperiod regimen (Parvin et al 2014; Wei et al 2020). Light quantity (intensity) and quality (color) are two significant factors influencing poultry behavior and productivity (Parvin et al 2014; Elkomy et al 2019; Soliman and El-Sabrout 2020).

In general, various researches have been conducted to investigate the effects of light intensity, source, and color on poultry performance (Parvin et al 2014; Borille et al 2015; Soliman and El-Sabrout 2020; Wei et al 2020), but the optimal light color and intensity for poultry, particularly chickens, is still a source of considerable debate.

Table 1 The main results regarding lighting aspects on improving poultry behavior, health, and production.

Effect-causing agents	Evaluated variables	Species	Main results	References
Different lights warmth	Performance and preference	Broiler chickens	The body weight in cool-warm LED treatment was greater than warm-warm LED, while cool-cool were intermediate. There was no effect of treatment on feed: gain in either trial. Birds in the cool-warm treatment exhibited a clear preferential pattern for warm light	Aldridge et al (2021)
Different white light LED	Hatchability and chick quality	Broiler chickens and chicks	The blue and red lights treatments could be used to improve hatchability and chick quality in broiler chickens	Archer (2018)
Lighting stress	Fluctuating asymmetry, heterophil-to-lymphocyte ratio, and tonic immobility duration	Broiler chickens	There was a significant difference between the heterophil-to-lymphocyte ratio and the tonic immobility duration between birds housed in continuous light (24L:0D) and a light-dark regimen (14L:10D). Results indicate that a continuous light regimen seriously negatively affects the welfare of birds.	Campo et al (2007)
Light intensity	Behavior and diurnal rhythms	Broiler chickens	Light intensity ranges from 1 to 40 lx did not affect melatonin levels or diurnal behavioral rhythms. Birds exposed to a light intensity of 1 lx rested more and preened less, indicating a reduced welfare state	Deep et al (2012)
	Reproductive and productive performance	Japanese quail	The exposure to 0.6 lx caused a significant decrease in sperm count and live sperm percentage, and increased dead sperm percentage. The application to program 0.6 lx causes an increase in stress index. The best feed conversion ratio was detected in normal daylight, 0.6 lx and 25 lx, respectively	Maty et al (2021)
Monochromatic red and blue light	Physiological and behavioral parameters	Broiler chickens	The red and blue monochromatic light during incubation can differently program the post embryonic development of broilers with possible consequences for their growth and welfare	Drozdová et al (2021)
Different light colors	Growth and reproduction performance	Japanese quails	Quails reared under red color light had higher body weight at five weeks of age, relative growth rate, the first 42 days of egg production, relative ovaries and testicle weights, sperm motility and fertility, and hatchability percentages than those raised under green and white light colors	Elkomy et al (2019)
	Egg-laying performance, egg qualities, blood hormone levels, and behavior patterns	Brown Tsaiya ducks	The applying red light illumination in the indoor laying duck raising system with positive results on egg-laying performance and acceptable egg weight, equivalent egg qualities compared to white and blue light	Su et al (2021)
	Production and egg quality	Laying hens	The different colors of light sources (blue, yellow, green, red, and white) did not affect production parameters or egg quality.	Borille et al (2015)
	Drinking behavior	Layer pullets	The pullets preferred to drink under the blue light the first six hours after the lights came on and under the white light within the last six hours before the lights went off	Li et al (2020)
Fluorescent lights and LED lights	Production performance and egg quality	Laying hens	The emerging poultry-specific LED lights yield comparable production performance and egg quality of W-36 laying hens to the traditional fluorescent lights.	Liu et al (2018)
LED bulbs and CFL bulbs	Growth, Stress, and Fear	Broiler chicken	LEDs result in better well-being and feed conversion when compared to CFLs bulbs. LEDs show improved production and well-being of broiler chickens compared to CFLs bulbs	Huth and Archer (2015)
Combinations of lights colors	Growth and productive performance	Broiler chickens	An environment under combinations of monochromatic lights of Green-Blue and Blue-Green exchanges can be used successfully to improve growth and productive performance in broilers	Cao et al (2012)
	Blood, skeletal development, and sexual development parameters	Laying hens	An appropriately staged spectral control using LED lights could positively affect the immune performance, bone development, and production performance of caged layer chickens during their brooding and rearing periods.	Wei et al (2020)
	Growth and immune response	Broilers chickens	The best results observed were in Green Light × Blue Light on performance, hematological parameters, biochemical parameters, tonic immobility duration, and open field test.	Seo et al (2016)

Birds use scanning behavior to collect visual data to make choices and decisions, such as seeking food (Fernández-Juricic et al 2004). Ultraviolet (UV) exposure, in general, influences bird development by promoting cholecalciferol synthesis in the skin (vitamin D_3). Light has been shown to improve feed intake, growth, and immunity in birds (Huth and Archer 2015; Soliman and El-Sabrout 2020). With the aim of improved poultry welfare and optimum production, UV light usage in poultry production is gaining traction. Poultry can see in the UVA wavelengths (320-400 nm) that encourage birds to express their natural behavioral activities such as foraging, drinking, walking, ground-pecking, and preening as well as dust-bathing. They also need the supplementation of UVB wavelengths (280-315 nm) which have physiological influences by stimulating vitamin D pathways, promoting skeletal development and growth, and impacting egg production (Rana and Campbell 2021). Therefore, the provision of UVA and UVB lights in poultry housing is important for improving poultry behavior, welfare, and productivity. Nevertheless, the optimal duration of UVB exposure in poultry farms and the possible adverse effects of UVB lights on birds are still being debated and require additional research investigations.

Light is a crucial environmental factor that affects bird behavior, development, production performance, health, and well-being (Parvin et al 2014; Soliman and El-Sabrout 2020). The emerging light-emitting diode (LED) lighting in poultry housing has drawn increasing attention from scientific and industrial communities. More energy-efficient, durable, affordable, and dimmable LED lights are increasingly finding applications in poultry production. LED light bulbs are becoming more used in poultry farms because, unlike CFL (compact fluorescent lamp), they are dimmable and even more energy-efficient than CFLs. They have increased energy savings in commercial poultry farming and positively affect the bird's growth and well-being (Huth and Archer 2015; Olanrewaju et al 2018). LEDs can result in better feed conversion and well-being when compared to CFLs. It is also notable that there are various types of LED bulbs, but they did not have the same effects on the bird performance, likely due to the spectrum of light each creates. In general, LED lighting can reduce stress and fear in reared birds compared to other traditional lightings (Mohamed et al 2014), and enhance their well-being. Reduced stress and fear responses may result in minor bird injury during handling and transportation. The reduced effect of stressors permits the bird to develop more efficiently and productively. In addition, Liu et al (2018) indicated that LED lights could be a viable replacement to traditional lighting in sustaining laying hen production performance.

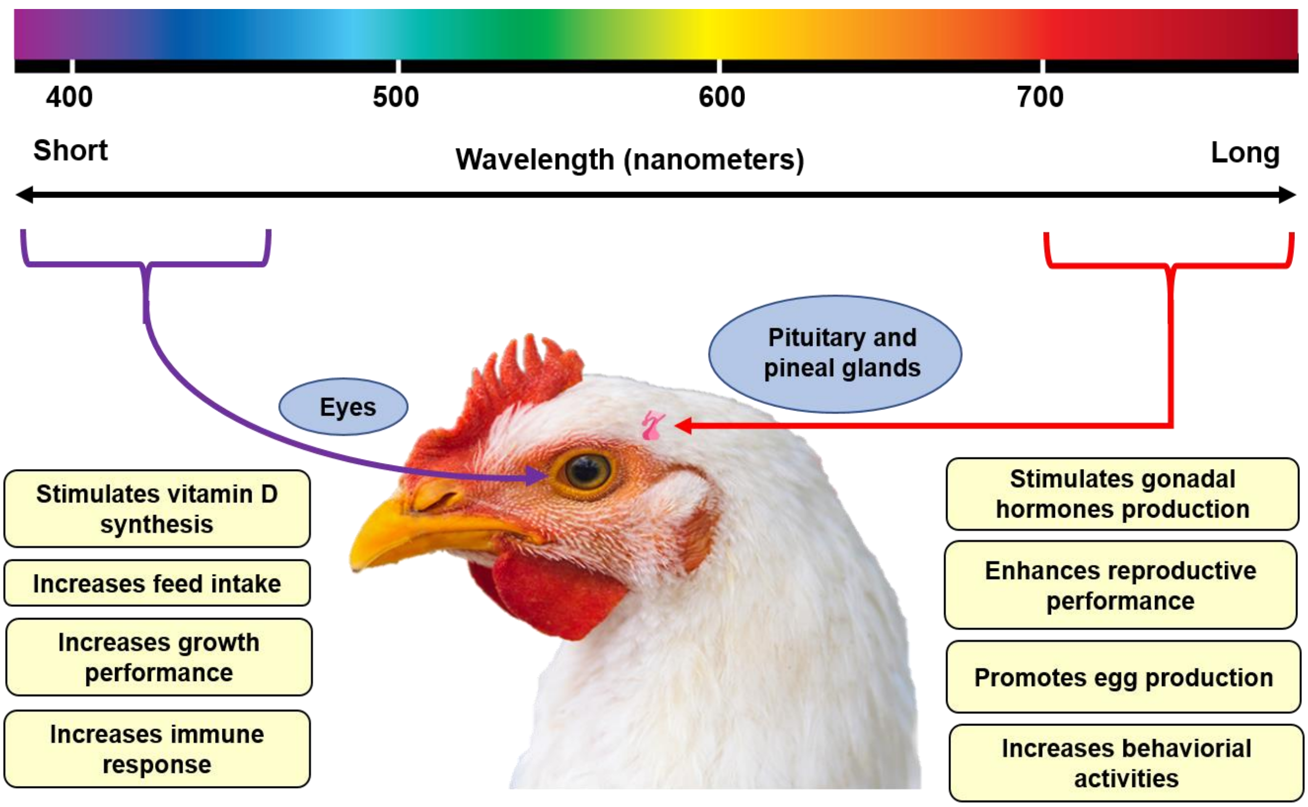

Figure 2 Potential physiological, behavioral, and productive responses of birds to a light stimulus.

2.1. Light color (wavelength)

As one of the primary light components that affects lighting quality, light color is determined by wavelength and has varying impacts on poultry performance and welfare. Several investigations using monochromatic light from LED bulbs have been conducted. Arbor Acres male broilers reared under combinations of monochromatic lights (white-blue, red-blue, green-blue, blue-green) exhibited superior growth and development than those reared under white lighting (Cao et al 2012). A mixture of monochromatic lights can be used successfully to promote growth and productive performance in broilers, resulting in higher body weight (>10%) and carcass (>25%) with a lower feed conversion ratio

(>15%). Oke et al (2021a) observed that switching from green to blue light at four weeks of age promoted ideal behavior and stimulated growth in broilers. On the other hand, Drozdová et al (2021) have investigated the exposure of fertilized chicken eggs under monochromatic red (632 nm) and blue (463 nm) light during incubation. They found that chick embryos incubated under red lighting had a higher body weight than those incubated under blue lighting, particularly during the rapid growth phase (days 18, 20, and 21 of age). The increased growth rate was related to behavioral features, primarily because embryos incubated under red lighting exhibited more passive (resting, standing, preening, dust-bathing) and less active behaviors (walking, foraging, fighting, wing-flapping) than embryos incubated under blue lighting.

Blue and red lighting had a significantly increased hatchability of fertile eggs (>5%) compared with the dark commercial treatment (Archer 2018). Furthermore, Sabuncuoglu et al (2018) found that blue and green LED lightings used on Japanese quail eggs during incubation positively influenced some behavioral features. These findings suggest that either of these lighting systems could be utilized to increase broiler chicken hatchability and chick quality. Using various types of lighting in commercial hatcheries can enhance efficiency by increasing hatchability and the quality of the chicks hatched (Archer 2018).

Less active chickens may grow faster, but the proactive phenotypic may be more physically active, with differential effects on postembryonic development and broiler welfare (Drozdová et al 2021). In agreement, Senaratna et al (2016) revealed that raising broilers under red light conditions increased weight gain and bird preference compared to other light colors. On the other hand, Seo et al (2016) reported that rearing broilers under shorter wavelength LEDs such as pure blue and bright blue can improve their growth and immune response at a later stage of production. They also found that an increase in the immune response can reduce disease risk and treatment expenses, resulting in improved survival rates and lower production costs, which support profitability. Furthermore, fear and stress were reduced when broilers were reared under blue LED light (Mohamed et al 2014).

Li et al (2019) conducted a study about a lighting preference test system to explore the layer preferences for four light-emitting diode colors: white, red, green, and blue. They discovered that layers preferred to stay in blue light when the light was turned on and in white light 4 hours before it was turned off. Consequently, pullets preferred blue light more than red light.

However, Campo et al (2007) and Hesham et al (2018) observed that abnormal behavior (aggression, fighting, and feather pecking) was significantly higher in birds raised under red light than in light of other colors due to the increased activity of birds under red light. Su et al (2021) also found that laying ducks reared under the red light showed more activity and less resting behavior than those reared under the blue light, and higher egg production performance than those reared under the white and blue light. On the other hand, Wei et al (2020) revealed that carefully staged spectrum management using LED lights can improve immunological performance, bone growth, and production performance of caged layer chicks during their brooding and rearing phases. The blue-green light enhanced serum Ig and serum glucose concentrations in layer chickens during phase 1 (0-13 weeks of age). At phase 2 (14-20 weeks of age), the yellow-orange light raised bone mineral density concentrations, encouraged sexual organ (oviduct and ovary) growth, advanced the age of sexual maturation, and improved layer chicken production uniformity. In addition, light colors influence layer pullets' drinking preferences. The pullets preferred to drink under blue light for the first six hours of the daylight, and under white light for the last hours. Therefore, most pullets preferred to drink under blue and white lights compared to other light colors (Li et al 2020). This preference could be attributed to light wavelength differences. The blue and green colors have shorter wavelengths (480 nm and 520 nm, respectively) than the red and yellow colors (700 nm and 580 nm, respectively), while the white color has a wavelength between 400-700 nm.

These findings verify layer preferences for light colors, providing insights for managing LED colors to fulfill pullet needs (Li et al 2019) and confirming that layer color preferences differ depending on the development stage. Furthermore, combined lighting colors can have a large future impact among researchers and breeders as a novel technique to enhance broiler and layer productive performance. Oke et al (2021b) stated that using green light for up to 28 days in combination with blue light increased broiler chicken growth, and manipulating light colors can improve chicken welfare and performance. Pan et al (2014) revealed that spectral composition has a significant impact on bird growth and physiology. According to the findings of their study, green-blue dual light has two side effects on chick body mass, depending on the green to blue ratio. When compared to monochromatic green or blue spectra-treated chicks, green-blue dual light with depleted and medium blue components decreased body mass while enriched blue component promoted body mass. Soliman and El-Sabrout (2020) concluded that more than 50% of the poultry research in this view showed that blue (450 nm) and green light (550 nm) had a positive impact on body weight (>3%); while red light (700 nm) increased activity and aggressive behavior in birds (>30%) with negatively influencing body weight. Therefore, it is recommended that red lighting be provided in the regions around the feeders and drinkers, and blue or green lighting be provided in other areas of the poultry houses for relaxing and other daily activities.

2.2. Light intensity (brightness)

Light intensity (also called illuminance or density), as one of the primary components of light that affects lighting quantity, can also influence birds' behavior and productivity (Patel et al 2016). It considerably influences birds' behavioral activities (walking, foraging, drinking, among others). In general, brighter light encourages more activity, whereas lower intensities are beneficial at controlling aggressive behaviors that can lead to cannibalism. Aldridge et al (2021) studied the usage of two common poultry-specific LEDs with varying light warmth (2,700 K and 5,000 K). They concluded that birds in the cool-warm treatment had a strong preference for warm light during the first and last hours of the 16-hour light period. Different light temperatures could enhance the market body weight of broiler chickens. Lighting patterns for birds are primarily used to stimulate and manage feed intake. Working on quails, Maty et al (2021) reported that exposing birds to high light intensity (25 lux) resulted in a significant improvement in feed conversion ratio and some constituent blood concentrations, such as PCV and hemoglobin concentrations, as well as some positive effects on bird's semen quality such as sperm live percentage. High light intensities (20-40 lux or 2-4 foot-candles) have been related to increased feed intake, rapid growth, and may positively affect the reproductive performance of birds; while low light intensities (3-5 lux) have been related to less movement and standing, as well as lower rates of fighting, feather pecking, and cannibalism (Buyse et al 1996). Therefore, it is recommended that broiler chicks be raised with a light intensity of at least 20 lux in the areas around the feeders and drinkers. Light intensity should be reduced in other areas for resting and other daily activities (Raccoursier et al 2019). Using this light intensity strategy, birds can choose between different area intensities based on their preferences and current behavior, improving their welfare. Breeders often employ modern electronic systems to enhance light intensity for short periods during grow-out to increase exercise and prevent skeletal and metabolic diseases.

2.3. Lighting duration (photoperiod)

The duration of light exposure substantially impacts the bird's growth, maturation, and reproduction. It affects poultry meat and egg production by activating growth and sexual hormones. The lighting duration is mainly determined by the age of the birds involved and the type of housing used (Patel et al 2016). In general, it is recommended to provide broiler chicks with 24 hours of light per day, gradually decreasing after the first days of the chick's life to ensure newly placed chicks locate feed and water and maximize intake by encouraging chick activity. During the production period, hens require at least 12 hours of daylight per day to lay regular eggs, and 14 to 16 hours of sunlight per day will keep them performing at their peak. Moreover, darkness is just as critical to bird's growth and health as light. Short photoperiods early in life are thought to restrict feed intake and impede growth. Researchers and breeders have investigated many light-duration strategies, and almost all of them have been shown to improve broiler growth and welfare (Patel et al 2016). However, the current review suggests that a minimum continuous dark period of 4-8 hours should be provided for birds based on their developing stages.

3. Density strategies to improve poultry behavior, health, and production

3.1. Importance of stocking density

Stocking density (SD) or crowding is one of the most prominent issues in the poultry industry and largely depends upon birds' behavior, welfare, health, and productivity (Figure 3). Stocking density can be defined as the amount of space available per bird. Moreover, it can also be defined as the number of birds reared in exact space (m^2) or broiler meat per unit area (Berg and Yngvesson 2012). Consumer awareness of avian welfare has grown in recent years, and as a result, consideration for higher-quality meat production has increased. People's perception of crowding causes serious welfare concerns to stimulate scientists to reduce SD and farmers to give their birds more space. Stocking density is considered the most influential factor that affects birds' welfare, physical activity, and production quality (Gomes et al 2014; Zhao et al 2021). Despite having several works on SD in poultry birds from the last few years (Table 2), conflict still exists between the bird's welfare interest that is more inclined towards more space given to the birds and the commercial producer who is willing to put more birds in the same space. Therefore, there is a diverse opinion about measuring the space and how much the bird needs (Dawkins 2018; Zhao et al 2021).

3.2. Stocking density effects on bird's behavior

Many studies reported a significant association between SD and the behavior of broiler chickens (Dawkins et al 2004; Abudabos et al 2013; Toghyani et al 2016; Zhao et al 2021). A study on broilers revealed a negative correlation between high SD and eating or drinking frequency (Beilmann et al 2005). When birds were reared under 1.7 and 14 kg/m^2, walking and sitting behaviors were more pronounced under the lower SD, and birds were involved less time in dozing and sleeping (Andrews et al 1997). Another study assessed broiler behaviors under different SDs (30-32, 36-38, and 42-44 kg/m^2 at 1700 g market age), revealed less locomotion and higher incidence of resting and standing in birds under higher SD (Son 2013). Furthermore, less feeding and drinking behavior were observed in commercial broilers when reared under the SDs from 27 to 39 kg/m^2 (Li et al 2020). Similarly, lower feeding and drinking behaviors were reported when birds were reared under 34 vs. 40 kg/m^2 SDs at 2000g market weight (Hall 2001). Another study reported that SD did not affect broiler chickens' drinking and eating behaviors (Iyasere et al 2012). Contrarily, Simitzis et al (2012) reported a higher frequency of feeding behavior and feeder visit in broiler chickens under 12.6 kg/m^2 SD than the recommended range of 27 kg/m^2. However, Li et al (2020) found a similar trend of feeding and drinking behaviors when broiler chickens reared under 27-39 kg/m^2.

A study regarding Thai crossbred chickens (Luang Hang Khao) revealed that stocking did not influence feather pecking frequency on different body parts except wings, bird reared under 12 birds/m^2 showed the highest frequency of wing pecking. The intense feather pulling was found in birds under 8 birds/m^2 (Huo and Na-Lampang 2016). This aggressive behavior of the birds could be due to their inherited genetic potential as Thai crossbred chickens have the traits of fighting; therefore, when the birds were reared under intensity grouping, they expressed a higher frequency of aggressive behavior and cannibalism (Huo and Na-Lampang 2016). In the study of Muscovy ducks, exploratory behaviors were more pronounced in birds reared under 9 birds/m^2 (Baeza et al 2003).

Table 2 The main results regarding density aspects on improving poultry behavior, health, and production.

Effect-causing agents	Evaluated variables	Species	Main results	References
Housing system and stocking density	Performance, carcass traits, blood indices, and meat quality	French pekin ducks	The meat contents of triglycerides and total cholesterol decreased in higher stocking density. Serum antioxidant indices were reduced in the plastic slatted floors. Housing on plastic slatted floors improved growth performance, carcass traits, meat cholesterol, and antioxidant status	Abo Ghanima et al (2020)
	Welfare	Broiler chickens	Differences among producers in the environment that companies provide for chickens have more impact on welfare than has stocking density itself.	Dawkins et al (2004)
Stocking density	Performance and Immunity	Chicks Ross 308 Broiler Chickens	Feed conversion ratio, body weight gain, and feed intake were improved significantly in 12 chicks' density compared to 18 chicks. Stocking density had no significant effect on mortality, as well as the relative weights of the spleen, bursa of Fabricius, abdominal fat, thigh, and breast	Astaneh et al (2018)
	Welfare, growth performance and carcass quality	Muscovy ducks	Starter ducks' final body weight and weight gain were reduced significantly as stocking density increased from 17 to 21 birds/m^2. The stocking density had no significant effects on feed/gain and mortality	Baeza et al (2003)
	Performance, relative carcass yield, gut microflora, and stress markers	Broiler chickens	High stocking density of 20 birds/m² negatively affected the performance and intestinal Lactobacillipopulationofbroilerscomparedtothelowstockingdensityof 10 birds/m²	Cengiz et al (2015)
	Performance, body conformation, and welfare	Broiler chickens	The high stocking density affects the parameters regarding conformation, performance and welfare of male broilers	Weimer et al (2020)
	Musculo skeletal development of pullets	Pullets	Overall, stocking density (247 cm^2/bird, 270 cm^2/bird, 299 cm^2/bird, and 335 cm^2/bird) during rearing had little impact on the musculo skeletal growth of pullets	Fawcett et al (2020)
	Welfare indices	Broiler chickens	Short-term high stocking density markedly increased broilers' stress and jeopardize their welfare	Abudabos et al (2013)
	Behavior and performance	Broiler chickens	The stocking density negatively correlated to the welfare behavior indicators and performance	Abo Alqassem et al (2018)
Air velocity and stocking density	Eating and drinking behavior and performance	Broiler chickens	Birds in pens with higher air velocity had better feeding behavior, weight gain, and feed efficiency. Increasing the stocking density reduced feed intake and weight gain but enhanced the feeding behavior of the birds	Beilmann et al (2005)
Temperature and stocking density	Acute phase proteins, heat shock proteins, circulating corticosterone and performance	Broiler chickens	High temperature and high stocking density was physiologically stressful to broiler chickens, as indicated by corticosterone, α1-acid glycoprotein, ceruloplasmin, ovotransferrin and heat shock protein HSP 70, but not detrimental to growth performance and survivability	Najafi et al (2015)
Cage height and stocking density	Behavior and response to stimuli	Laying hens	The changes in horizontal and vertical space over the ranges we studied had little effect on behavior other than feeding behavior.	Albentosa et al (2007)
Perch availability and stocking of density	Immune status	Broiler chickens	As density increased, bursa weight and bursa/body weight ratios significantly decreased. The addition of perches to the pens also significantly decreased the bursa weights and bursa/body weight index	Heckert et al (2002)

Lower incidence of feeding and drinking were observed in laying hens when reared at high SD (Albentosa et al 2007). In a study of Leghorn pullets, SD influenced feeding and standing behaviors, and these behaviors were more pronounced when birds were reared at a density of 23 birds/m^2 (Hofmann et al 2021).

3.3. Stocking density impacts on bird's health and welfare

Higher SD is considered the main stressor in poultry and is generally associated with endocrinological alterations and demotes the bird's welfare. A study assessed the tonic immobility of commercial broilers under different SDs (6-56 kg/m^2 considering 2600g market weight) and revealed higher fearfulness in birds reared under higher SD. During the growing phase of broiler chickens, antibody titters against New Castle Disease and Infectious Bronchitis were raised when birds reared under low SD (Abudabos et al 2013). Other studies reported a higher incidence of footpad dermatitis in broiler chickens with increasing SD (455-622 cm/bird) (Sorensen et al 2000; Dozier et al 2006). A study of male broiler chickens revealed high lesions score when reared at 40 and 45 kg /m^2 SD (Dozier et al 2005). Another study reported reduced lymphoid organ weight of broiler chickens when reared at higher SD (Ravindran et al 2006). Reduced immunity in broiler chicken was also reported by another scientist when stocked at high SD (Heckert et al 2002; Palizdar et al 2017).

Higher SD also impacts biochemical response, as the studies reported higher heterophile, and stress hormones when in commercial broilers when reared under higher SD (Najafi et al 2015; Astaneh et al 2018). When Arbor Acres and Ross 308 broiler chickens were reared with increased SD, it influenced blood biochemical profile, and ALT, AST, urea, and creatine were linearly increased (Nasr et al 2021). Other studies reported reduced total protein, albumin, globulin, ALT, AST (Abudabos et al 2013), cholesterol, and HDL (Sahin and Kucukm 2001) in broiler chickens reared at high SD. Increased H/L ratio was also noted in broiler chickens when reared under high SD (Cengiz et al 2015). In a study of Ross 308 male broilers, decreased H/L ratio was also reported due to overcrowding stress (Chegini et al 2018). However, another study did not find any difference in lymphoid organ weight, blood glucose level, and passive immunity in broiler chickens when reared at 120, 90, 60, and 30 bird/m^2 (Qaid et al 2016).

When Muscovy ducks were reared under 9 birds/m^2, it showed better welfare aspects and overall performance (Baeza et al 2003). Another study on Pekin duck revealed that the incidence of footpad dermatitis did not influence by increasing SD (Xie et al 2014). In a study of Japanese quail, higher SD significantly reduced the immune response (Erisir and Erisir 2002). When reared at high SD, increased spleen weight was also reported in Japanese quail (Mahrose et al 2019).

Working on white leghorn hens, Hofmann et al (2021) revealed that the number of blood lymphocytes was lower in both the rearing and laying phase at high SD and severe feather pecking at the tail, footpad, and comb lesions were also reported when the bird stocked at 23 birds/m^2.

3.4. Stocking density effects on productivity of the bird

Stocking density largely influences the total performance of poultry birds such as broiler chickens, and several studies reported adverse effects of higher SD on bird's growth and productivity (Petek et al 2014; Chegini et al 2018). Increasing the SD of birds slowed development, growth, and increased oxidative stress (Jobe et al 2019). High SD (20 birds/m^2) can adversely affect broiler chickens' growth performance and market weight (Cengiz et al 2015). Poor growth performance and feed efficiency were also reported in Arbor Acres chickens when stocked at 45 kg/m^2 (Li et al 2019). Similarly, another study reported negative effects on feed consumption and weight gain of commercial male broiler chickens when reared under 35 to 45 kg/m^2 for 49 days (Dozier et al 2005). Depression in feed intake was also reported when high SD was provided to fast-growing broilers and reported this decline because of limited access to feeders and drinkers (Feddes et al 2002). Moreover, a poor feed conversion ratio was reported in broiler chicken when reared at 16 birds/m^2 (Houshmand et al 2012). A higher mortality rate (5%) was also noted in broiler chickens when reared at 29 kg/m^2. Furthermore, most extended bodies and keel length and narrower breast and pelvic were also reported at 37 kg/m^2 (Weimer et al 2020).

Improved carcass weight and meat yield were noted when Arbor Acres broilers were reared at 15 bird/m^2 (Abo Alqassem et al 2018). Broiler chickens reared at high SD (more than 15 bird/m^2) significantly reduce the carcass quality, especially thigh, breast yield, and lower breast fillet (Abo Ghanima et al 2020). On the other hand, contradictory studies reported that broiler chickens reared at different SD did not exhibit any significant difference in growth parameters and carcass traits (Nogueira et al 2013; Kryeziu et al 2018; Obeidat et al 2019). In agreement, Avian 48 and Ross 308 broilers, when reared at 40 and 30 kg body weight/m^2, did not show any difference in growth performance (Ligaraba et al 2016; Palizdar et al 2017). Furthermore, increasing SD did not influence mortality rate in a study of fast-growing broiler chickens (Thomas et al 2004; Simsek et al 2011) and carcass traits (Zuowei et al 2011). Similarly, meat quality traits of different broiler strains did not influence SD when reared between 10 and 16 birds /m^2 (Moreira et al 2004). Working on laying chickens, SD influenced musculoskeletal traits, especially the amount of cartilage on keel bone and leg muscle weight in leghorn pullets. Birds reared at low SD (247 cm^2/bird) had the heaviest leg muscles and the lowest cartilage amount on keel bone (Fawcett et al 2020).

In a study of White Pekin ducks, the increasing SD did not influence the birds' mortality during the day of hatch to forty-two days of age. However, increasing SD negatively affects growth performance (Xie et al 2014). Another study on Pekin ducks reported that birds reared under 8 birds/m^2 for four weeks and 4 birds/m^2 until market age revealed the highest weight gain and optimum market age. Moreover, breast and thigh yield dropped in 8 birds/m^2 reared birds (Osman 1993). Similarly, in European countries, the general trend for SD is 6-8 birds/m^2 for Pekin duck (Rodenburg et al 2005).

In general, higher SD reduces bird performance, especially feed conversion ratio, weight gain, and increases mortality. Moreover, the incidence of footpad lesions increases in broiler chickens with increasing SD. Higher SD has been associated with major stress in poultry birds resulted in higher pecking in laying hens and aggression in broiler chickens. From the previous literature, the recommended SD for laying chickens raised in a non-cage system throughout the production stage is 12 birds/m2 (30 kg/m^2). The optimal SD for caged layers is 370 cm^2/bird throughout the rearing stage and 550 cm^2/bird during production. Broiler chickens reared at a medium SD (18 birds/m^2 or 36 kg/m^2) had better productive performance and welfare than those raised at high (20 birds/m^2) or low (14 birds/m^2) densities, according to Nasr et al (2021). As a result, medium-density was the most cost-effective option. The recommended SD for layer and broiler breeder chickens is 30 kg/m^2. Japanese quail, ducks, and turkey can also better be stocked at SDs of 200 cm^2/bird, 30 kg/m^2, and 0.3715 m^2/bird, respectively.

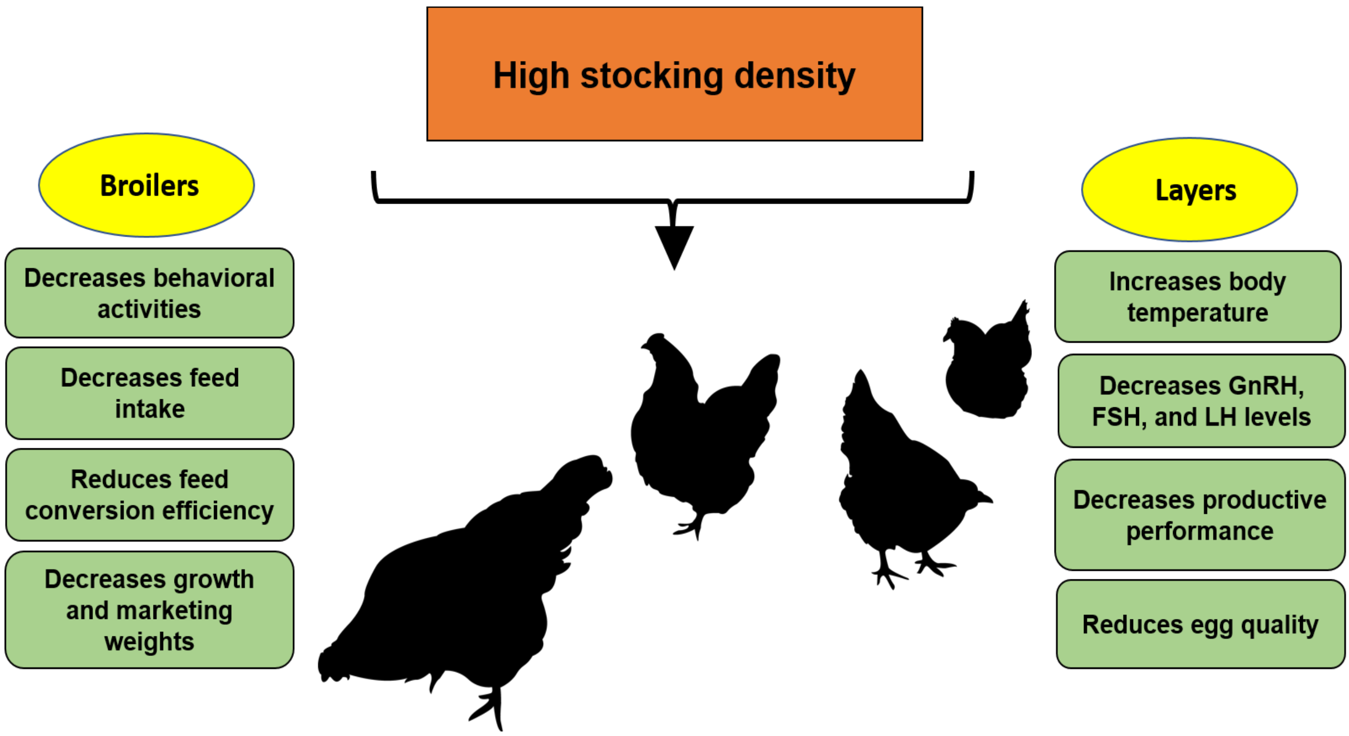

Figure 3 Potential impacts caused by high stocking density on birds.

4. Dietary strategies to improve poultry behavior, health, and production

The main results regarding dietary aspects on improving poultry behavior, health, and production showed in Table 3.

4.1. Effect of dietary strategies on bird's health and welfare

The current commercial chicken is the consequence of years of intensive genetic selection for growth and egg production. Intending to express the genetic potential of these high-yielding birds, balanced nutrition is mandatory and considered a contributing factor in the economics of poultry enterprise. The primary concern for poultry nutritionists is to optimize the diet that can improve birds' health. Therefore, poultry health and ultimately welfare aspects are considered significant criteria for developing dietary strategies in poultry (Whitehead 2002; Zuidhof et al 2015). Protein modifications (amino acids) and energy contents can alter productivity, especially growth, morphometrics, intestinal health, egg production, and egg quality traits (Husveth et al 2015). Imbalanced minerals and vitamin or their deficiency may cause welfare problems, e.g., lesions. Similarly, the ideal dietary strategy can reduce heat stress in poultry birds. Furthermore, the genetic disorders in broiler chickens (cardio muscular and skeletal deformities) can be reduced by a dietary modification that decreases the fast muscular growth (Reiter and Bessei 2000; Whitehead 2002).

The principal aim of formulating broiler diets is to achieve maximum body weight at all ages; however, poultry nutritionists continuously improve the feed strategies to formulate the diet of meat-type birds according to the age requirement. Manipulation of broiler diet to slow down the growth during earlier age could be advantageous as bones are more suspectable to lesions that affect broiler health and welfare (De Jong et al 2012). However, the later stage of broiler life requires a higher nutrient diet that can allow the birds to achieve compensatory growth and develop the ideal market age. This occurs because modern broiler genotypes are less suspectable to footpad dermatitis (FPD) and have fewer incidences of skeletal deformities (Meluzzi et al 2008; Skrbic et al 2015). Another dietary strategy to improve the incidence of tibial dyschondroplasia (TD) in broiler chickens is fasting. Providing a fasting period of almost 8 hours a day could be beneficial for birds to utilize all the nutrients effectively and enhance walking ability that ultimately improves birds' health. A study on broiler chickens revealed that the provision of meals 2-4 times a day enhances walking ability with improved gait and reduces FPD incidence (Su et al 1999; Whitehead 2002).

Table 3 The main results regarding dietary aspects on improving poultry behavior, health, and production.

Effect-causing agents	Evaluated variables	Species	Main results	References
Unpredictable feed delivery	The development of fault bars	*Gallus gallus domesticus*	Feather traits, including fault bars and feather growth, can be used as indicators of negative welfare in chickens	Arrazola and Torrey (2019)
Dietary insoluble fiber	Behavior and hunger	Broiler breeders	High-fiber diets can alleviate the feeling of hunger currently experienced by broiler breeders, and a high ratio of insoluble fiber may improve the well-being of the birds	Nielsen et al (2011)
Feeding management	Body weight and carcass uniformity	Pullets	Birds on the high fiber treatment consumed more feed and had the highest feed conversion ratio. Scatter feeding increased flock uniformity	Zuidhof et al (2015)
Protein source	Development of footpad dermatitis	Broiler chickens	Mixed protein source diet increased body weight and improved footpad dermatitis significantly. The incidence and severity of footpad dermatitis were highest in birds reared on wood flooring	Cengiz et al (2013)
Dietary probiotic supplementation	Performance, relative carcass yield, gut microflora, and stress markers	Broiler chickens	Dietary probiotic supplementation did not affect the relative carcass yield, weight of lymphoid organs, serum malondialdehyde, corticosterone, nitric oxide, and plasma heterophil: lymphocyte, stress indicators, total aerobes, *Salmonella*, and *Lactobacilli* in the intestines of the broilers	Cengiz et al (2015)
	Growth, carcass traits, and lymphoid organs	Japanese quail	Birds fed a diet supplemented with probiotics (*Lactobacillus*) at 0.02 g/kg showed the highest spleen weight significantly. Probiotic supplementation diminished the stressful effect of crowding	Mahrose et al (2019)
Propolis supplementation	Heat stress, growth performance, immunity, and stress indicators	Broiler chickens	Dietary use of propolis as a feed supplement can reduce some of the detrimental effects of heat stress and high stocking density in broilers	Chegini et al (2018)
Different feeding times	Performance	Broiler chickens	It is possible to change conventional feeding management's (T1 = feeding at 6:30 a.m.; T2 = 50% feeding at 6:30 a.m. and 50% at 3:30 p.m.) by the dual feeding system (T3 = feeding at 11:00 a.m.; and T4 = feeding at 3:30 p.m.)	De Avila et al (2003)
	Shell quality and oviposition time	Laying hens	Mean eggshell thickness was increased by 3-5 µm per h delay in feeding time when hens were housed in individual cages but was not when birds were housed on litter floors. Mean oviposition time was delayed relative to lights on by 5 min per h delay in feeding time	Backhouse and Gous (2005)
Timing and durations of feed restriction	Reproductive characteristic	Broiler breeder females	The birds of feed restricted had higher proportional weights of the ovary and oviductal the age of sexual maturity. The cL HRH-I levels and gonadotrophin contents in the pituitary followed that of growth in response to feeding levels and timing of feeding, related to the timing of the onset of lay	De Jong et al (2002b)
Vegetable and animal protein diet	Growth, excreta quality, nutrient digestibility, and bone development	Broiler chickens	In general, parameter responses indicated that the animal protein diet was superior to the vegetable protein diet	Hossain et al (2013)
Whole wheat supplement	Growth performance and intestinal function	Broiler chickens	Compared to the control group, wheat seed feeding increased gizzard weight, presented higher trypsin, α-amylase, and lipase activities were detected in the jejunal digesta when the diets contained whole wheat	Husveth et al (2015)
Feeding frequency	Indicators of hunger and frustration	Broiler chickens	Scattered feeding, feeding twice a day and a combination of these two feeding strategies do not significantly improve broiler breeder welfare during rearing as indicators of hunger have not changed	De Jong et al (2005)
	Performance, egg quality, and bone strength	Laying hens	The split feeding system showed a potential strategy to improve shell quality by offering a better match between Ca supplementation and requirements in the laying hen	Molnár et al (2018)
	Performance, eggshell quality, incubation traits, and behavior	Laying hens	Twice a day feeding improves behavior and split feeding improves both egg production and behavior in broiler breeders. However, no effects were observed on eggshell quality and incubation traits	van Emous et al (2021)

Balanced dietary electrolyte, i.e., Na, K, and Cl, is generally considered a major factor influencing the quality of litter and the severity of FPD in broiler chickens. Several studies on broiler chickens and turkey reported that a high level of the dietary electrolyte leads to increase water intake that ultimately influences the litter quality and increases the incidence of FPD, and in some cases, enhances the severity (Koreleski et al 2010; Jankowski and Zdunczyk 2014). However, another study reported a higher incidence of FPD in growing female turkeys when fed with 0.25% additional sodium in diet (Lichtorowicz et al 2012). Similarly, when broiler chickens were fed with a 1.45% potassium level, it negatively affects litter quality and enhances the incidence and severity of FPD (Fuhrmann and Kamphues 2016). Dietary protein concentration is the second main factor that can affect litter quality and FPD severity. The studies on commercial broilers reported that birds fed with all vegetable protein sources had the highest incidence of FPD than those of having mixed protein (animal + vegetable protein source) in their diet (Cengiz et al 2013; Hossain et al 2013). Similarly, another study noted a higher incidence of FPD in broiler chickens when fed with corn and soybean meal diet than the birds fed with diet have the inclusion of poultry by-product meal (Eichner et al 2007). A study concluded that providing optimal dietary electrolytes, protein source, biotin, and some feed additive in the diet of broiler chickens and turkey could reduce the incidence and severity of FPD (Swiatkiewicz et al 2017).

The most common strategy for broiler breeders is feed restriction that is being practiced all around the globe. Provision of 2-2.5 hours of feeding and prolonged restriction could be helpful during the production stage to optimize the bird's body weight, reduce the chance for fat deposition on female reproductive traits and facilitate egg production (Nielsen et al 2011). However, feed restriction could be associated with aggression and severe feather pecking, especially on the tail and vent, leading to cannibalism in advanced stages (Strochlic and Romero 2008). Generally, a feather score is a major indicator for determining a bird's health. It is common to measure feather coverage score, feeding motivation, and stress response to make an ideal dietary strategy in broiler breeders (Arrazola and Torrey 2019). Feed restriction in poultry is considered controversial due to remaining feed motivation and from a welfare point of view as not fulfilling one of the five-freedom systems, i.e., birds should be free from hunger (van Krimpen and De Jong 2014; Tolkamp and D'Eath 2016). Thus, the latest dietary strategies supported higher satiety and reduced hunger with the increased feed allotment by diluting feed contents (qualitative feed restriction) of broiler diets (van Emous et al 2015).

4.2. Effect of dietary strategies on bird's production performance

The requirement of animal protein fulfillment for the fast-growing human population provoked scientists to genetically select the chickens for a higher growth rate. This selection, on one side, improved the adult body weight and increased the level of appetite in boilers and broiler breeders (Zuidhof et al 2014). It has been observed that offering *ad libitum* feed to broiler breeders causes a reduction in egg production and increases mortality with age (Renema and Robinson 2004). It is mandatory to restrict feeding to avoid excessive body weight, maintain reproductive capacity and health in broiler breeders. As improved genetic progress for higher body weight and increased nutrient requirements of modern broilers demand more feed restriction in broilers, it was restricted to 25-33% of required *ad-libitum* feed (De Jong et al 2002a).

Usually, eggs are laid early in the morning (Zakaria et al 2005; Zakaria and Omar 2013), and after 1 hour of laying, the next ovulation occurs (Etches 1987). Egg formation starts up with 6 hours of albumen formation in which protein and amino acids are involved (Leeson and Summers 2005). After 18 hours, calcium is required for the formation of eggshells. The nutrients are unavailable during the eggshell formation because the morning feed is digested 4-5 hours before shell formation; to fulfill this requirement, nutrients are deducted from the bone (Bar 2008). Suppose the daily required amount of feed is offered in a twice a day feeding strategy by dividing into two portions, then, it could increase the availability of nutrients for eggshell deposition and egg formation (Farmer et al 1983a), which ultimately improve Ca's utilization (Farmer et al 1983b; Roland and Farmer 1984). It has been observed that offering feed twice a day can improve the eggshell weight (Lewis and Perry 1988), and the number of eggs produced by broiler breeder females can also be improved (Taherkhani et al 2010; Moradi et al 2013; Soltanmoradi et al 2013).

On the other hand, some researchers observed no effect of twice a day feeding strategy on the eggshell thickness, eggshell weight (Samara et al 1996), and the number of eggs produced (De Avila et al 2003; Backhouse and Gous 2005; Londero et al 2015, 2016). It has been reported that feeding a standard diet twice a day did not affect the overall egg production (Samara et al 1996; De Avila et al 2003; Backhouse and Gous 2005; Londero et al 2015, 2016). However, on the other hand, improvement in egg production while feeding a standard diet twice a day has also been observed (Taherkhani et al 2010; Moradi et al 2013; Soltanmoradi et al 2013). Overall reviewing the previous studies, the older literature explained that twice a day feeding strategy did not alter the egg production except (Londero et al 2015, 2016), while the recent studies (onward from 2008) showed higher egg production in breeders fed twice a day. This inconsistency between different studies might be caused by their genetic differences explained by (van Emous and Mens 2021). Compared with the broiler breeders four decades ago, current broiler breeders have higher growth and production potential, which resulted in longer fasting durations and increased feed restrictions (De Jong and van Emous 2017). The prolonged fasting durations may negatively influence the hypothalamus regarding reduced gonadotropin secretion, which ultimately negatively affects ovulation, leading to reduced egg production (Morris and Nalbandov 1961). As far as the commercial layer is concerned, split feeding strategies in organic farming (van Krimpen et al 2018) and aviary system (Molnár et al 2018) did not affect egg production. Twice a day feeding system did not also affect the egg weight of commercial layers (Samara et al 1996; Backhouse and Gous 2005; Soltanmoradi et al 2013; Londero et al 2015, 2016). However, the other studies on breeders claim the contrary findings in which twice a day feeding strategy positively influenced the egg weight (Spradley et al 2008; Taherkhani et al 2010; Moradi et al 2013). The variation in the literature finding might be due to the variation in the length of experimental duration, explained by (van Emous and Mens 2021).

4.3. Effect of dietary strategies on the bird's behavior

It has been observed that the concentration of plasma corticosterone is improved due to increased feed restriction (Mormede et al 2007). The increase in plasma corticosterone might be associated with behavioral stress and adaptive metabolic adjustment to cope with the lower level of energy supply. Furthermore, stress and fasting may affect chickens' metabolism and immune response (Sherlock et al 2012). Some strategies are being considered to decrease negative behavioral parameters associated with restricted feeding, like the scattering of feed on bedding material, environmental enrichment, and restricted daily feeding. These strategies help the chickens regarding the availability of object stimuli and the natural habit of forage and pecking (De Jong et al 2005; Leone and Estevez 2008). Zuidhof et al (1995) suggested that the negative impact of feed restriction on welfare can be managed by diluting the diet's nutrient density.

A significant effect has been observed on the behavior of chickens when comparing once and twice a day feeding strategies. Chickens spent less time on object pecking and foraging and more time sitting and eating when fed twice a day. Although the amount of feed is the same while feeding twice a day, spending more time eating might be due to calm eating behavior. Furthermore, the chickens fed twice were observed less active as they spent more time sitting, standing, and resting which showed comfort (van Emous and Mens 2021). Previously, it has been reported that pullets showed less sitting, resting, and comfort when reared on restricted feeding, which might be caused by higher satiety and lover state of hunger (Hocking et al 1996). De Jong et al (2003) indicated that increased standing behavior of chickens is associated with an increase of eagerness of meal which reflects its state of hunger. When fed twice a day via scatter feed or trough, it has been reported that pullets caused more walking behavior (De Jong et al 2005). The difference in the behavior of chickens when fed twice a day is attributed to the difference in the level of feed restriction during the rearing and laying period (van Emous and Mens 2021). It has also been observed that chickens spent less time on foraging and object pecking when fed twice a day (van der Haar and van Voorst 2001; De Jong et al 2005; van Emous and Mens 2021). In another study, a reduced level of object pecking was observed when broiler breeders fed twice a day, reflecting less frustration (Savory et al 1996; De Jong et al 2002b). During the rearing period, especially the stereotypic object pecking was observed, which was hardly observed during the laying phase (Sandilands et al 2005; De Jong et al 2005; van Emous et al 2015), which might be due to the higher amount of feeding during laying phase (van Emous and Mens 2021). The lower level of object pecking in birds fed twice a day is explained as eating time cannot be spent on other activities such as object pecking (Mason et al 2006; van Emous et al 2015; van Emous and Mens 2021).

Higher feeding frequency is associated with feeding, including feeding anticipation, standing, and comfort, which stimulated the chickens to perform object pecking (Dawkins 1989). Domestic chickens spend more time pecking (Dawkins 1989) because they usually explore the environment by using their beaks to forage (Schütz and Jensen 2001). Chickens feel more saturation when feed is offered throughout the day as feed is consistently present in the gastrointestinal tract, and satiety may cause reduced need to peck; meanwhile, pecking is the natural behavior repertoire of chickens to find and eat (Hetland et al 2004). van Emous and Mens (2021) observed that feeding birds twice a day had a positive influence on their behavior, as birds spent very little time drinking and eating in the afternoon when they were treated with once a day feeding. Furthermore, the chickens spent less time drinking and eating when fed twice a day because only 50% of daily feed was offered in the morning. Offering feed once a day influences resting behavior at the end of the day, which can be detrimental to fertilization and mating processes. Most matings are usually done at the end of the day (Harris et al 1980; Bilcik and Estevez 2005). Twice a day feeding strategy positively influenced mating activity and egg fertilization (van Emous and Mens 2021).

5. Final Considerations

Environmental conditions such as lighting, density, and dietary, have become critical factors in poultry farming particularly with the current climate and economic challenges. The current review focuses on recent advances in poultry house lighting, density, and dietary factors. These factors can potentially affect the whole bird's life and interest traits. Light management, for example, has a significant impact on birds beginning with incubation and continuing through marketing. They do not affect only birds' development and growth but can also have long-lasting effects on birds' behavior and welfare. This review also presents different practical strategies that could be successful used to ameliorate heat stress on birds in some tropical and subtropical regions. Good management and optimal husbandry programs enhance birds' behavior (activities), health (immunity), productive performance (feed intake, body weight, among others) as well as welfare, resulting in more profitable production.

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Conflict of Interest

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