European Chicken Commitment: Natural Lighting Guide for Broiler Chickens

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Introduction

This guide offers a comprehensive review of the natural light requirements of the European Chicken Commitment (ECC). The guide touches on the different properties of light and how broiler chickens perceive light. This guide also examines how natural lighting improves chicken welfare and guidance for commercial application of the ECC natural lighting requirements.

What is the European Chicken Commitment (ECC)?

The scientific literature has well-established that chickens are sentient beings that show a range of emotional responses. Chickens are capable of experiencing pain and fear, and alternatively, can express excitement and curiosity when given the opportunity to perform highly motivated natural behaviours, such as foraging, perching, and dust bathing.[1] Yet, how broiler chickens are bred, housed, and slaughtered in today's standard intensive systems means chickens spend their rather short lives experiencing pain, frustration, and poor physical health under barren conditions that severely limit their behavioural opportunities beyond eating, drinking, and sitting.[2–4]

With the support of over 30 European non-profit organizations, the European Chicken Commitment (ECC)[1] was created in 2017 as a unified corporate ask to address the most significant welfare issues in broiler chicken production. The ECC criteria improve chicken welfare as evidenced by science and best-case practical examples. Companies signed up to the ECC have committed to provide chickens with more space to live, and with natural light and enrichment important for behavioural expression and occupation. The ECC requires the adoption of slower growing breeds with proven higher welfare outcomes, humane slaughter without conscious inversion, and third-party auditing against the ECC standards. Over 400 food companies across Europe have signed up to the ECC, which is set to benefit millions of broiler chickens each year.

ECC lighting requirements

Regarding the lighting program, the ECC requires:

- **At least 50 lux of light throughout the day, including natural light**
- **Lighting conditions that comply with all European Union (EU) animal welfare laws and regulations, regardless of the country of production, meaning:**
    - At least 80% of the littered areas must be illuminated in chicken barns during the light period, and
    - The lighting pattern must follow a 24-hour rhythm and include six or more hours of daily darkness. At least four hours of the daily dark period must be uninterrupted, excluding periods when the lights are gradually dimmed.

[1] https://welfarecommitments.com/europeletter/

Key recommendations on natural lighting for broiler chickens

Natural light is crucial for chicken welfare and behaviour, as it offers a fuller spectrum of light, including essential UV wavelengths like UV-A and UV-B, which are vital for their health, natural behaviours, and overall well-being. Natural lighting can be provided inside commercial broiler barns through several different methods. Regardless of the method, the total area of the natural light openings should be equivalent in size to a minimum of 3% of the barn's total floor space and spaced evenly across the barn to ensure enough light enters to meet the daytime minimum light intensity of ≥50 lux throughout the barn.

Windows

- To ensure all chickens within a flock benefit from natural daylight, existing barns should retrofit windows in the roof or side walls making up at least 3% of the total floor space. For new barns, it is recommended that windows are equivalent in size to at least 5% of the total floor area.
- Windows should ideally be made of reflective or low-emissivity glass to maximize the amount of visible light and UV-A wavelengths available to the chickens while also minimizing the entry of solar heat indoors (see Table 4). Window glass almost entirely blocks the entry of UV-B wavelengths into the chicken house.
- Side wall windows are preferred over roof windows for as this window positioning provides a more natural, dynamic light environment with varying intensities throughout the day. Roof windows provide more uniform light throughout the barn, but lacks the natural variability. Windows should be made of thick, double-glazed glass and can be installed with coverings (for example, shutters, blinds, slats, or curtains) in places where heat stress is an issue to limit the entry of light during the hottest parts of the day.

Solar tubes

- Solar tubes allow natural light to be provided in barns that cannot accommodate window installation due to ventilation systems, or when extremes in climatic conditions mean that temperatures do not allow for windows. For solar tubes, enough tubes must be installed to achieve an average of 50 lux of daytime light throughout the barn.
- Solar tubes allow 92% of visible light to pass through into the barn but completely block UV-B wavelengths and the amount of UV-A entering the barn is ≤1.5%.

Open-sided & curtain-sided barns

- In comparison to windows or solar tubes, curtain-sided barns allow the fullest spectrum of natural light to enter the barn, including UV-A and UV-B wavelengths, with minimal distortion even when permanent thin plastic curtains are in place.
- The adoption of open-sided and curtain-sided barns is encouraged in geographies with suitable climates as these houses allow for the greatest entry of natural light and use natural ventilation to cool the birds, aerate the litter, and to dissipate the accumulated ammonia. Therefore, supplementary artificial ventilation systems are unnecessary due to the open layout of these barns. However, temperature management can be more challenging in these houses during extreme temperatures, so these barn set-ups are not suitable for all climates. For instance, in regions with consistently very cold (<10°C) or hot (≥30°C) conditions. In very hot climates, the entry of strong solar rays can cause chickens housed in open- or curtain-sided barns to show significant signs of heat stress, such as panting.

The different properties of light

Light as an environmental factor can be described by its properties:

- **the wavelengths (colour),**
- **the intensity (brightness),**
- **the source of light (natural *vs.* artificial),**
- **and the schedule/duration of light provided (light-dark rhythm).**

These aspects of light are highly variable according to the time of day, season, and climatic conditions.

1. **Wavelength:** A property of light that is part of the electromagnetic spectrum

Visible light is the part of the electromagnetic spectrum that can be perceived visually by the eye. The colour of visible light is determined by the spectral wavelength.

- Humans can see visible light in the range of 410-750nm with peak visual sensitivity at 550-560nm (green light wavelengths). In contrast, chickens can see a wider range of visible light with their eyes, from 360-750nm which includes light in the **ultraviolet-A (UV-A)** range (315-400nm; See Figure 1).[5,6] Additionally, chickens have a higher sensitivity for blue and red light spectra than humans with light sensitivity peaks at approximately 480nm and 630nm in addition to a photosensitivity peak at 540-577nm (green light).[5–7]

There are also parts of the light spectrum that cannot be perceived visually but impact all living beings, for example, UV-B light (280-315nm). UV-B light is important for the birds' own endogenous vitamin D synthesis. Research has shown improved vitamin D synthesis, through the provision of UV-B light, for male broilers leads to improved growth, higher body weights, and a reduced risk of bone development and mineralization deficiencies, including rickets and tibial dyschondroplasia (Figure 2).[8,9]

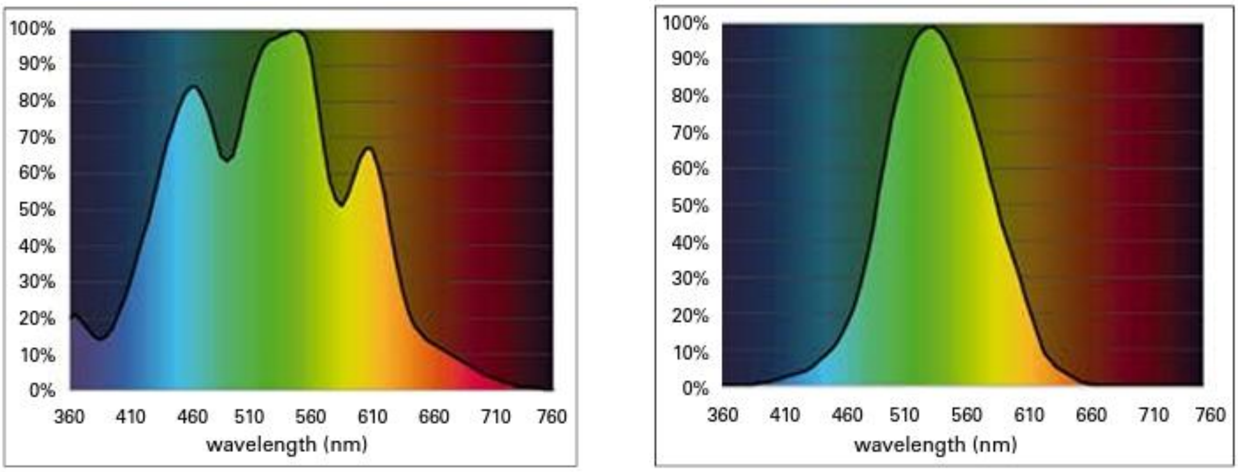

Figure 1. (a) The visible light spectrum of domestic chickens (*Gallus gallus domesticus*) and **(b)** humans (*Homo sapiens*) showing the photosensitivity peaks of each species at different light wavelengths (Source: Hy-Line International, 2017).

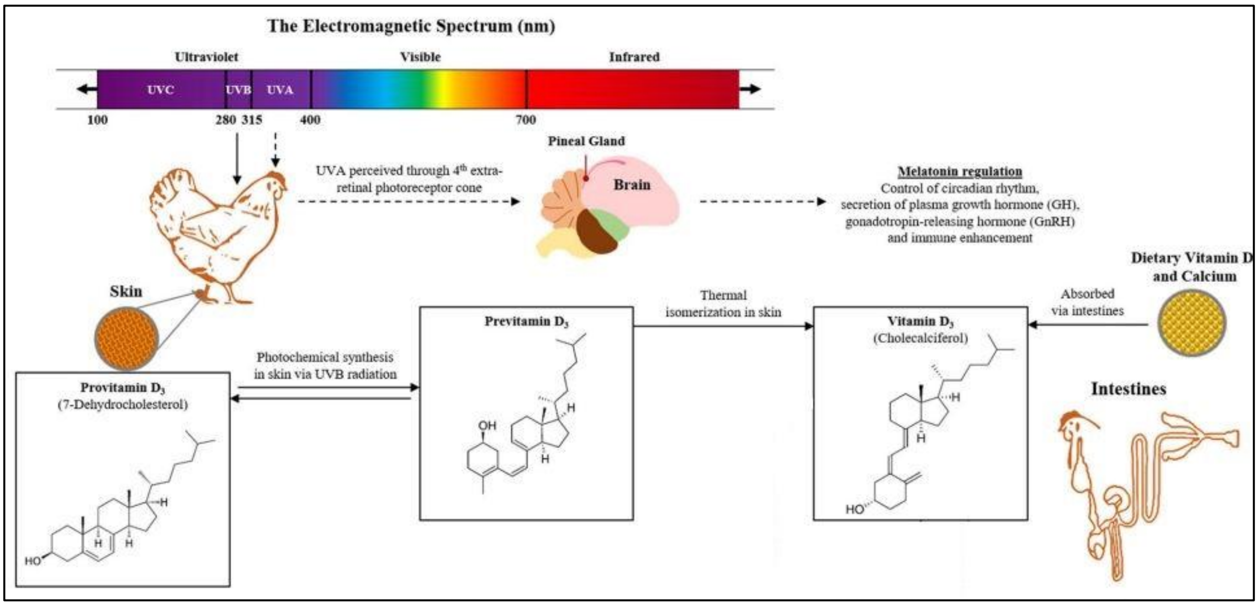

Figure 2. The absorption pathways for ultra-violet light in chickens. UV-A light wavelengths are perceived by UV retinal photoreceptors, but also through extra-retinal photoreceptors in the pineal gland, which regulates the production of melatonin. UV-B light is absorbed through the skin in chickens and is responsible for the endogenous synthesis of vitamin D that supplements vitamin D obtained through the diet (Source: Rana and Campbell, 2021).

2. **Intensity:** the strength or amount of light and heat produced by a specific source.

Light intensity is measured as the amount of visible light or illuminance (lumens) covering a specific surface area, or the perceived brightness by the eye. Light intensity is typically expressed in **lux** (lumens/m^2) or **footcandles** (lumens/ft^2). 1 foot candle is equal to approximately 10.76 lux.[10] Brighter lighting has a higher light intensity and a larger lux/footcandle value. Whereas darker lighting conditions have a lower light intensity and a smaller lux/footcandle value.

Traditional light meters measure light intensity in lux at the portion of visible light spectrum that appears brightest to humans, which is 550-560 nm.[7] However, the issue arises that these units (lux or footcandles) refer to how humans perceive light intensity. Given the visual system of chickens differs from humans, **chicken lux** ("clux" or "gallilux") is seen as a better measure of how chicken's perceive light intensity.[7,11] Chicken lux is a measurement of the amount of visible light or illuminance covering a specific surface adjusted by the spectral sensitivity curve of chickens. In contrast to lux, chicken lux considers the UV-A light (360-400 nm) that chickens can see, but humans cannot. In addition to UV-A light, light meters that record in chicken lux calculate light intensity across the photosensitive spectral peaks specific to chickens. Chicken lux can be ≥50% brighter than traditional lux measurements, which reflects the different spectral composition between light sources (Table 1). Therefore, chicken lux is viewed as a more accurate measurement of light intensity regardless of the source of light (for example, natural light versus incandescent bulbs).[7,11]

Additional guidance outlining best practices for measuring light intensity in broiler barns is available from the European Union Reference Centre for Animal Welfare – Poultry SFA.[12]

Table 1. Light intensities in different indoor and outdoor environments, including the native habitat of the red junglefowl (*Gallus gallus*), the ancestral species of domestic broiler chickens (*Gallus gallus domesticus*).

Environments	Average light levels (lux)	Average light levels (chicken lux)
An office	500[13]	≥750*
An indoor room with no windows & only a single ceiling-mounted artificial light source	9-116[14]	≥13.5-174*
Red junglefowl habitat: Daytime near the ground underneath the forest canopy	250-2,500[14–16]	≥375-3,750*
Red junglefowl habitat: Daytime in open areas	2,000-70,000[14,16]	≥3,000-105,000*

[13] Recommended average light levels for an office meant for reading, writing, & data processing

[14–16] Ground level light levels measured at 1.3-2 m above ground level between 900-1500 during both summer and winter months underneath the canopy of primary and secondary forests in South Asia (Brunei, Indonesia, Southern India). Open area light levels measured in open outdoor areas with no trees or other cover between 900-1500 from March to September in South Asia (Indonesia & Southern India)

*Estimates are based on reporting that chicken lux can be ≥50% brighter that traditional lux depending on the spectral composition of the light being measured[7]

3. **Sources of light** can be categorized by whether the light provided is natural or artificial:

- **Natural light** can come from two sources:
    - Sunlight: Direct light from sun, high intensity
    - Skylight: Diffuse reflection of light particles, lower intensity
- **Artificial light** comes from non-natural, man-made light sources, which includes:
    - Compact fluorescent lights (CFLs),
    - Incandescent,
    - Halogen, or
    - Light-emitting diode (LED) light bulbs.

4. **Lighting schedule:** The length and frequency of light and dark periods.

- Natural light follows a day/night rhythm according to the movement of the sun, with long periods of light (‘photophase’ or ‘photoperiod’), followed by long periods of darkness (‘scotophase’ or ‘scotoperiod’).

- The duration of both the light and dark parts of the lighting schedule can impact behaviour.

Within a chicken barn, the length of the daily light and dark periods can be dependent on the amount of natural light allowed to enter the barn, and where the barn is positioned in terms of the earth's surface (longitude and latitude) as well as seasonal differences. The presence of artificial lighting within the barn also impacts the length of the daily light and dark periods and can be altered under intensive production practices to limit birds' movement and feeding activity.

The visual system of chickens

How chickens detect light

Chickens detect light through:

- **Retinal photoreceptors in their eyes, and**
- **Extra-retinal photoreceptors in the pineal gland & hypothalamus within their brains** (Figure 2).[5,6,17–21]

The structure of a chicken eye

Like other vertebrates, both eyes of a chicken include cornea, iris, pupil, lens, and a retina. The front of each chicken eye is covered by the transparent cornea, which provides protection to the eye and helps focus light on the retina. Behind the cornea is the iris, a muscular structure that controls the amount of light that enters the eye by changing the size of the pupil. The pupil is the opening in the centre of the iris where light passes through. The lens is located behind the pupil and helps to focus the entering light on the retina. Finally, the retina is a layer of light sensitive cells (retinal photoreceptors) at the back of a chicken's eye. When the photoreceptors within the retina are triggered by light, nerve impulses are sent through neurons in the optic nerve to the brain where a visual image is formed.[6]

Chickens have **six types of visual photoreceptors** in their retinas (Figure 3):

1. **Rods**
   - Allows chickens to see in grey scale for night-time vision under low light conditions.

Four types of single cones:

Cones give chickens **tetrachromatic vision**, providing them the ability to see wide range of different colours of red, green, blue, and violet/ultra-violet wavelengths of visible light in brighter light conditions. Unlike rods, cones require a minimum intensity of light to function.

2. **Red cones** - peak light absorption: 571 nm
3. **Green cones** - peak light absorption: 508 nm
4. **Blue cones** – peak light absorption: 455 nm
5. **Violet/Ultra-violet (UV) cones** - peak light absorption: 415 nm)
   - Humans only have trichromatic vision (red, green, and blue single cones) and are unable to see UV light. In contrast, chickens also have violet/UV cones that allow them to see within the UV-A light range (360-400nm) and a wider range of violet light (400-420nm).[6,21]

6. **Double cones**

- Double cones are a unique feature for the eyes of reptiles, fish, and birds. Double cones are thought to provide chickens with **enhanced motion detection**.[6,18,19,22]

In addition to external eyelids, chickens have a nictitating membrane - a translucent third eyelid, located underneath their eyelids. The nictating membrane functions to keep the eye moist and protected while maintaining vision even when closed. These third eyelids are found in other bird species, sharks, and some reptiles and mammals.[23]

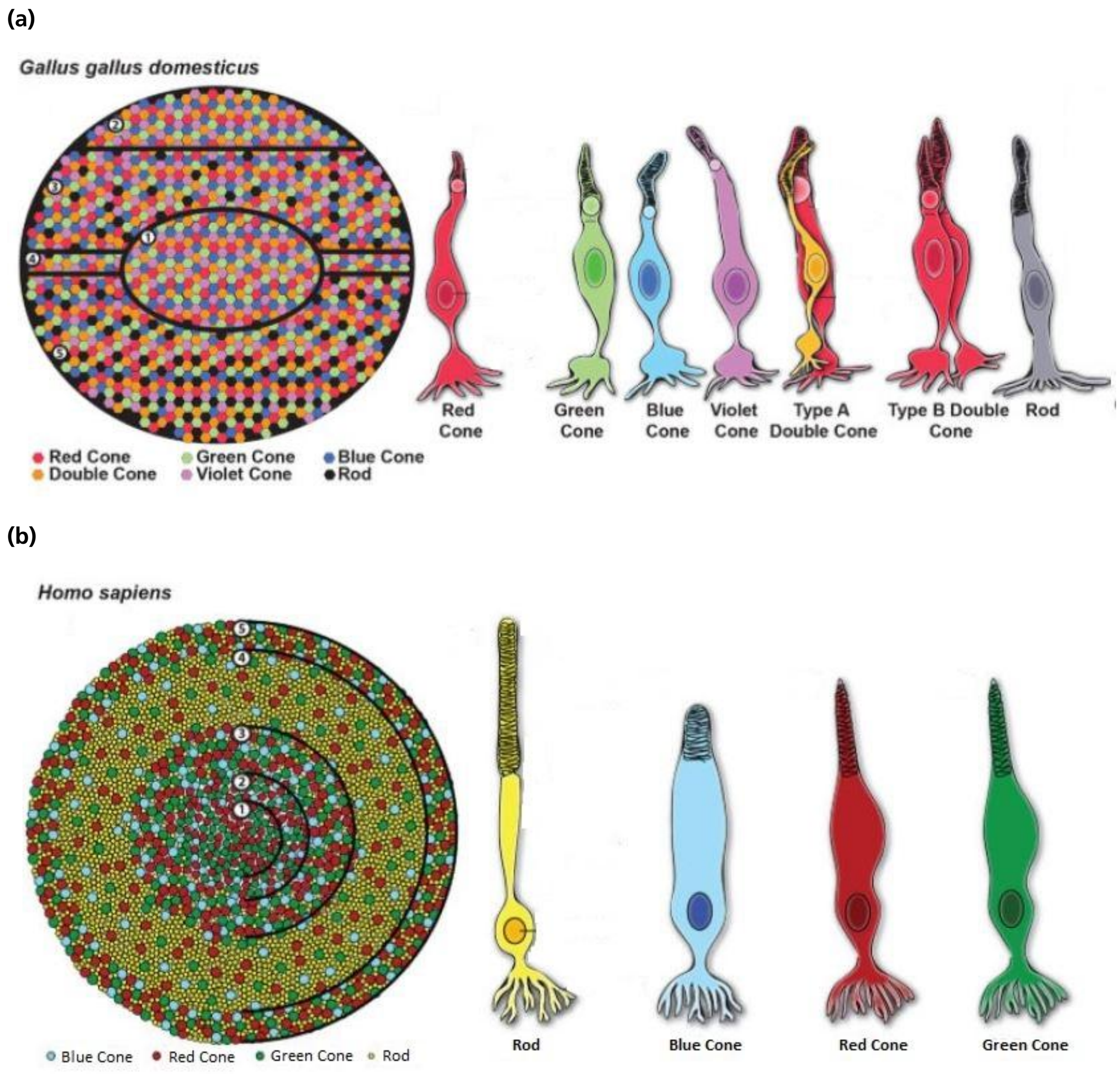

Figure 3. The patterning of light-sensitive visual photoreceptors in the retinas of (a) chickens (*Gallus gallus domesticus*) and (b) humans (*Homo sapiens*), including the types of retinal photoreceptors found in each species (Adapted from Viets *et al.,* 2016).

How chicken vision compares to other species

The visual system of chickens is one of the most complex amongst vertebrates, which gives chickens highly developed vision. In comparison to humans, chickens have greater visual sensitivity, including more developed colour vision, the ability to see UV wavelengths, faster processing of visual stimuli, and enhanced motion detection. In addition, chickens, like other avian species, have **lateralized brains**, so can process visual information separately with each eye simultaneously.[24] For instance, chickens will use the right eye for detailed visual detection, such as searching for food particles when foraging.[25] Chickens use their left eye, which is better for far distance sightedness, for predator detection, identifying novel stimuli, and socially for distinguishing between familiar and unfamiliar conspecifics.[24,26,27] Table 2 provides a comparison of the visual systems of chickens versus humans, including structural and physiological differences that contribute to their different visual capabilities.[6]

Table 2. A comparison of the visual systems of chickens (*Gallus gallus domesticus*) and humans (*Homo sapiens*). (Adapted from Wisely *et al*., 2017).

Chicken Visual System[6,18,24–29]	Human Visual System[30]
Eyes make up ≥50% of cranial volume	Eyes make up 5% of cranial volume
300° monocular field of view with the eyes positioned on either side of the head	80° monocular field of view (40° per eye)
30° binocular visual field	120° binocular visual field due to close position of both eyes on the face
Each eye can move independently and process information separately	Eyes move and process information together
7.5 million cones & 1.3 million rods per eye (3:1 cone-to-rod ratio)	4.6 million cones & 92 million rods per eye (1:20 cone-to-rod ratio)
Tetrachromatic vision	Trichromatic vision
4 types of single cones: red, green, blue, & UV	3 types of single cones: red, green, & blue
Double cones for enhanced motion detection	No double cones
Poor night vision (few rods)	Better night vision (higher number of rods)
Faster visual processing (150-200 images per second)	Slower visual processing (25-30 images per second)
Can perceive flickering in light sources that operate in low frequency ranges (*e.g.*, fluorescent lights)	Unable to perceive flickering in low frequency light sources

Why do chickens need light?

Light not only affects the visual perception of chickens allowing them to see different shapes, shades, and colour hues, but light also controls many key physiological processes for chickens.

I. To see (vision)

Chickens rely on their vision as their primary sense. Chickens have better visual perception and acuity in bright versus dark light, which allows the dense array of single and double cones in their eyes to function. Chickens have highly developed visual abilities in the light, including the ability to see a wide array of coloured light and fine-tuned movement tracking, which allows them to:

- identify resources in their environments, including feed, forage, water, and shelter,
- communicate,
- detect predators, novel objects, and distinguish between familiar versus unfamiliar conspecifics.[5,19,24,31,32]

II. Required for normal endocrine functions

Chickens not only 'see' light with their eyes but also sense through extra-retinal photoreceptors. The extra-retinal photoreceptors in the pineal gland are responsible for the production and release of melatonin, which maintains the bird's circadian rhythm. The extra-retinal photoreceptors in the hypothalamus controls homeostasis and reproductive function (Figure 2).[17,33]

What does natural light provide for chickens?

A natural circadian lighting rhythm, including:

I. Bright daytime lighting

In standard European production, chickens are reared under a minimum of 20 lux of light during daylight hours. In contrast, the natural lighting systems in broiler barns report average daytime light levels of 54.6 to 555 lux, depending on the method providing natural light, the size of the inlets, and if measured in open versus shaded areas of the house.[34–39] Natural light provides the optimal lighting conditions for broiler chicken welfare: a full spectrum of daylight, including UV wavelengths, bright daytime light, and continuous daily dark periods to support their natural circadian rhythms.

When incorporating natural light into broiler housing, a producer should aim to achieve average light levels of ≥50 lux, measured at bird eye level, across 80% of the floor space of the barn. These levels should be achieved within 7 days after chick placement and maintained until 24 hours before the birds are slaughtered. The ECC criterion for ≥50 lux light intensity supports the physical health of broiler chickens and allows them to engage in normal active daytime behavioural patterns important for their welfare.

Today's broiler chickens are descended from red jungle fowl (*Gallus gallus*), which spend the majority of the daylight hours engaged in foraging (60.6% ground pecking & 34.1% scratching) even when fed at regular intervals in captive settings.[40] Research has also demonstrated that daytime light intensity greatly impacts the expression of foraging behaviour in broiler chickens. Broilers spend more time foraging during the daytime in 50 or 200 lux *vs.* 5 lux artificial lighting.[31,32] Modern chickens maintain the

preference to be active and feed, forage, drink, walk, and preen in brighter lighting throughout their lives.[31,32,41–46]

It is well-established by research that modern chickens have highly-developed colour and UV vision that they rely on for identifying resources, social communication, and predator detection, with better visual acuity in bright versus dim light.[5,19,31,32] Like humans, chickens are unable to view colour at night as their retinal cones are not active in low light levels. Therefore, **low levels of daytime lighting may not allow chickens to see colour**.[28]

Under low daytime light intensities, studies show broilers spend the majority of time resting with little variation in behaviour between the light and dark periods.[31,32,41–43] Research has shown broiler chicken flocks under low levels of daytime lighting are less active overall, have disrupted flock behaviour and melatonin release, more mortalities and footpad lesions, and develop heavier, larger eyes, which may cause pain and impair their vision.[31,32,41–43,47–51]. Suppliers may be hesitant to adopt higher daytime light intensities over concerns of reduced bird performance, increased costs of production, and heightened levels of damaging feather pecking and aggression. However, several studies has shown no significant impacts of higher daytime light intensities on bird FCRs (*e.g.,* 2 lux: 1.49 *vs.* 20 or 100 lux: 1.55;[52] 20 lux: 1.67 *vs.* 90/30 lux gradient: 1.65)[53] and final body weights,[35,47,52,53] including studies comparing natural light (85 lux sunlight + 3.37μ/Wcm^3 UV *vs.* 11.4 lux artificial light + no UV)[54] and artificial light intensities up to 100 lux.[52] The added ventilation costs from natural lighting can be offset by renewable energy sources, for example, by installing solar panels on the barn roof. A 50-lux light level is easily met with natural inlets, and in dimmer conditions, the cost of supplemental LED lighting is minimal due to its high energy efficiency.

The incidence of feather pecking (gentle and severe feather pecking) and aggression (*i.e.,* a bird facing another bird with the feathers raised on its head or neck, with the acting bird jumping, kicking, or pecking at the other bird's head) in broiler chicken is influenced by the light source - specifically the wavelength composition and the colour of the light, but not light intensity. For example, a 2007 study showed female 6-week-old Ross 308 chickens showed more gentle and severe feather pecking when housed under biolux than warm white lighting at 5 and 100 clux.[55] Unlike warm white lighting, biolux lighting includes UV-A wavelengths, which likely enhanced the illuminance of the birds' plumage making more visually attractive for the chickens to investigate through pecking. When light intensity is constant (30 lux), both male and female Ross broilers were more active and perform more aggressive pecking behaviour in red light versus green, blue, or white light from 1 to 35 days of age.[56]

A related study showed Ross broilers had a low incidence of aggressive feather pecking overall, but statistically more aggression (0.72 pecks/bird/day up to 3.84 pecks/bird/day) when the light intensity increased from ~150-390 lux under red and ~310-950 lux under blue light.[57] However, this study's behavioural findings are somewhat confounded by the experimental set-up and lighting schedule. These chickens were housed in cages with mesh flooring on a 23 hours light: 1 hour dark daily lighting pattern, which differs from the 16-18 hours light: 6-8 hours dark daily program used in commercial broiler operations. The existing broiler chicken research shows aggression and feather pecking occurs infrequently making up 0.01-0.13% and 0.51-1.86% of their daily time budget, with an individual chicken showing 0.72-3.84 pecks/bird/day, at 4-6 weeks of age.[55–57] Much of the concern around brighter lighting leading to more aggression or damaging feather pecking in broiler chickens comes from management concerns from laying hens, turkeys, and broiler breeders. However, these poultry are typically raised to a much older age (laying hens: ≥72 weeks, turkeys: 9-24 weeks, broiler breeders: 60-65 weeks of age) than broiler chickens that are slaughtered between 5-7 weeks of age. In these farmed poultry, the heightened levels of injurious behaviours often coincide with reduced behavioural opportunities during the onset of sexual maturity and/or feed restriction.[58–60]

Most studies to date have focused on the lighting preferences of fast-growing conventional broiler strains. However, newer research out of the Netherlands has looked at the light preferences of fast-(Ross 308) and slower-growing (Hubbard JA757) commercial broilers across different ages, time of day, and performing different types of behaviour (primarily classified as active *vs.* inactive).[61,62] The study compared the short-term preference of these breeds across four intensities: 0.2, 20, 50, and 1000 lux (approx. 5, 24, 63, and 1200 gallilux).[61] The second study examined the breeds' preferences over time for different light intensities (15 and 100 lux; approx. 10.6 and 67.5 gallilux) and colours (sky blue and jungle green).[62] The results reinforced the close link between the lighting conditions and behaviour of broiler chickens. Both breeds preferred to eat and drink in the brighter (50 & 1000 lux) versus darker lighting conditions (0.2 & 20 lux). Chickens from both breeds exhibited significantly more locomotion, including play and general movement, as well as foraging behaviours, such as ground pecking and exploratory pecking, and standing activity under jungle green and the brightest light conditions. In contrast, both breeds preferred to rest under dimmer sky blue lighting. This pattern likely reflects their evolutionary origins. Modern broilers descend from junglefowl, which forage on the forest floor in brighter light but retreat to tree branches to rest, where the light filtered from the sky is blueish.[62] Both fast- and slower-growing broilers increased the amount of time spent in the lowest light intensity and more time resting and inactive prior to slaughter. However, the shift towards spending more time in dim light (15 *vs.* 100 lux) was more noticeable in the slower-growing JA757 chickens. In contrast, the fast-growing Ross 308 chickens maintained a consistent focus on feeding and resting throughout their life, which resulted in a less pronounced change in light preference.[62,63]

It is important to emphasize that both breeds, regardless of age, spent time in all the varying light intensities provided in these studies.[61,62] Across all ages, both the Ross 308 and JA757 consistently spent the early (5:00-7:00) and late (23:00-1:00) parts of the daylight period in the brighter light intensities (50 and 1000 lux), likely corresponding with activity and feeding.[61,62] The slow-growing JA757 birds specifically preferred the brightest lighting (1000 lux) at the beginning and end of the light period throughout their lives. This underscores the importance of offering a range of light intensities throughout the day. This closely mimics the environmental variation found with natural lighting conditions. Unlike uniform lighting throughout the barn, a diverse lighting gradient allows chickens to select lighting conditions that best support their behaviour at any given time of day, rather than being confined to a single, consistent lighting level. However, it is critical that commercial application of a daytime lighting gradient provides a meaningful range of light intensities (up to 1000 lux) and spectra reflective of natural lighting conditions during the day. It should avoid stark contrasts in lighting intensity throughout the chicken barn (for example, 20-40 lux in ~10% of barn with ~90% at 2-5 lux during daytime hours). In addition, sufficient space must be available to the full flock to ensure all birds can engage in behaviours requiring brighter (active behaviours) versus less bright lighting conditions (inactive behaviours) - especially given active behaviours, such as locomotion, foraging, and play require more space to perform than inactive resting.

II. Daily period of continuous darkness

The day/night rhythm of natural light is controlled by the sun's movement across the sky. The duration of light and dark periods each day will often vary based on location's position relative to its distance from the sun during different seasons. Broiler chickens are descended from red jungle fowl (*Gallus gallus*), which reside in the wild in southeast Asia and India, where the length of daylight ranges from 10-14 hours, with 10-14 hours of darkness each day, throughout the year.[64–68]

Domestic broiler chickens require a sufficiently long continuous dark period of 6-8 hours each day, as recommended by both research and industry guidelines.[28,48–50,69–73] Six to eight hours of darkness each day allows broilers to obtain the undisturbed rest needed for normal hormone function, eye development,

neurological performance, and good leg musculoskeletal health.[48–50,69–72] A large-scale study of 89 broiler flocks across Europe showed the incidence of severe lameness was reduced from 16.9 to 7.4% in flocks as the artificial lighting systems incorporated increasingly longer daily dark periods 0 to 6.5 hours.[69] A 2008 UK study of 176 flocks showed each one hour increase in daily darkness from 0 to 8.5 was associated with a 0.079 improvement in the average gait score for broiler flocks.[70] Similarly, studies have shown broilers have improved mobility, better footpad condition, and lower mortality rates when raised with 7-8 hours of continuous daily darkness.[48,71,71] The expression of normal behaviours signifying a good level of welfare, including litter pecking, preening, dust-bathing, and movement, also disappear when the light period exceeds 16-17 hours each day (7-8 hour dark periods).[50] Longer daily dark periods of 6.5 hours were statistically associated with flocks that are less fearful of humans and appear more content, energetic, and positively associated as measured by qualitative behavioural assessment (QBA).[69]

Broilers housed under near-constant light (23 hours light: 1 hour dark) show increases skeletal and leg problems, reduced activity, and disrupted melatonin production This disruption leads to fragmented sleep, sleep deprivation, unsynchronized behavioural patterns, and physical signs like heavier eyes that may impair the birds' vision and cause pain.[48,49] Providing dark periods during early life is essential for normal bone development in broilers, due to the role of melatonin in regulating bone growth.[74] By seven days of age, chicks raised under constant light (24 light, no dark period) already had suppressed melatonin secretion, disrupted circadian rhythm gene expression, and elevated fear and stress responses, which can result long term consequences for their physical health and welfare.[72]

III. Variation across the broiler barn

A diffuse gradient of natural light within broiler chicken barns can effectively replicate the varying light levels found between open and shaded areas outdoors during daylight hours, closely mimicking the lighting conditions in the natural habitat of the modern broiler chicken's wild ancestor, red junglefowl. This dynamic lighting scheme can significantly enhance chicken welfare by creating functional zones within the barn that allow birds to express a wider range of species-specific natural behaviours. For example, dimmer areas, such as those beneath enrichments like straw bales or elevated platforms, provide shelter and protection, allowing birds to rest undisturbed during the day, like the shaded forest floor where wild junglefowl rest during the midday heat. In contrast, brighter areas (≥50 lux) covering most of the barn (*i.e.,* at least 80% of the available littered floor space) promote physical activity and stimulating behaviours like foraging, locomotion, standing, preening, and play, all of which require enough brightly lit space to allow all chickens within a flock the opportunity to perform simultaneously.[62,75,76] This variation in lighting levels not only supports the chickens' natural circadian rhythms but also encourages a full behavioural repertoire rooted in the evolutionary traits of their wild ancestors.[31,32,42,44–46,77,78] In the wild, red junglefowl are naturally drawn to brighter, open areas (1,000-4,000 lux) for foraging and other active behaviours, while retreating to dimmer cover (100-1,000 lux) to rest during the heat of midday (Figure 4).[16,66–68] By mimicking these natural lighting gradients, broiler barns can provide an environment more conducive to the birds' natural behavioural repertoire, promoting both their physical and psychological well-being and overall welfare.

However, when sources of natural (or artificial) light are minimal and not evenly distributed across the barn, the result can be very little brightly lit area for the birds and severe contrasts in light intensity across the barn during the light period, which negatively impact the welfare of broiler chicken flocks. With natural lighting, this can occur if too few windows or solar tubes are installed in the walls or roof, and the natural light openings account for less than 3% of the recommended total floor area of the house. Important daytime light variation within the barn can also occur when all nature light inlets are concentrated in one section of the barn. With artificial lighting, installing lights in only one area, such as on top of feeder lines, has been shown to create significant light contrasts. Feeder-only artificial lighting can lead to ≥80% of the barn in almost complete darkness (≤5 lux) when the feeder lights are lit to 20-40 lux during the light period.[39,52,79]

Severe contrasts in daytime lighting across the barn fail to provide enough well-lit space for all chickens within a flock to engage in light-stimulated active behaviours, including movement, foraging, and exploring, that are important for good welfare. Without bright daytime lighting levels throughout the barn, broilers are unable to engage with enrichments that require high visual acuity, including perches, scattered grain, and straw bales. Most chickens in these systems are in near-constant darkness in the predominantly unlit floor space causing the same disruptions to their normal diurnal physiological and behavioural rhythms as broilers reared under uniform low intensity lighting. The severe contrasts in daytime light intensities can also lead to higher bird occupancy in brighter areas during the day resulting in poor localized litter quality and potentially increasing the risk of contact dermatitis lesions. If bright lighting is only available around the feeders, increased bird occupancy around the feeders could reduce feed consumption as broilers choose to spend more time near the walls to avoid the increase competition for feeder space.

Figure 11. A commercial barn housing an ECC-approved broiler breed in the United States with windows installed along the side walls to provide a minimum of light intensity of 50 lux during daylight hours. Artificial lights are also installed on the roof to supplement, as needed. This image shows the distribution of windows, in addition of platform enrichments, creates a subtle gradient of natural light across the barn during the midday hours. This natural lighting gradient allows the chickens to choose different functional areas to express different behaviours. For example, the dimmer area under the platform enrichment to rest. Or, underneath the well-lit window area to perform light-stimulated active behaviours (Source: Compassion in World Farming).

IV. Gradual lighting transitions at dawn and dusk

The purpose of the ECC lighting criteria is to ensure that the light intensity is sufficient throughout life (*i.e.,* including before pop holes are open to the wintergarden or range), throughout the house (*i.e.,* through good distribution of light sources in the house), and throughout daytime hours. Regarding the latter (throughout daytime hours), it is important for welfare that the transition in light intensity at dawn and dusk is progressive. It is not expected - neither recommended - that light is kept at a minimum of 50 lux during the earliest hours or the latest hours of the day. A sudden drastic increase or decrease in the light levels can be very startling to broilers causing the birds to stress, panic, and in some cases, scratching and piling injuries.[80] At a minimum, the ECC lighting criteria of 50 lux intensity applies to at least 8 hours of continuous light daily.

V. Ultraviolet (UV) light wavelengths

As discussed earlier, modern broiler chickens descend from red junglefowl, native to Southeast Asia. Red Junglefowl primarily reside in dry deciduous or bamboo forests, forest edges near roads and clearings, or in areas of regrowth close to human settlements (Figure 5). These native birds will feed in open areas during the morning and late afternoon daylight, where they receive the full range of UV light directly from the sun. The red junglefowl will then rest during the mid-afternoon heat under the forest canopy in the shorter brush and tall grasses. Under the forest canopy, the spectrum of sunlight is more filtered by the trees and overheard vegetation, so the range of UV light will be more limited, but UV-A wavelengths are still present.[66–68,81]

Figure 5. A wild male red junglefowl along the edge of a bamboo forest in Southeast Asia (©aopichet, shutterstock)

Like their ancestral counterparts, modern broiler chickens have highly developed colour vision. Natural light provides a wider spectral range than artificial light sources and includes UV-A wavelength that chickens can see. The addition of UV-A from natural lighting improves the visual acuity of modern broiler chickens indoors. Although the UV spectrum range will be marginally diminished when entering the barn through the windows or other light permeable material.[54] UV-A wavelengths can still enter through these natural light inlets, and the daytime light spectrum inside of naturally-lit barns more closely resembles where red junglefowl seek refuge underneath forest canopy in the late afternoons.[66,67,81].

Studies show that ultraviolet (UV) light helps modern broilers more effectively detect UV-reflective plants, seeds, and insects. This ability is especially important for young broilers, who rely on UV cues to explore and understand their environment during the first weeks of life.[5] A 2025 study showed young broilers preferred to feed under UV *vs.* non-UV light in the first two weeks of life for both fast and slower-growing broiler lines (Ross 308 and Hubbard JA757), but this preference disappeared as the birds aged. Chickens also need lighting with UV wavelengths in order to recognize UV feather markings and colour saturation differences in the plumage of other birds for normal social communication.[33,82,83] The UV wavelengths in natural light sources for chickens has been shown to further improve bird welfare by facilitate the performance of active behaviours, such as walking or foraging, that requires lighting conditions that allow for improved spatial orientation and visual discrimination skills.[54,84–86]

What are the welfare benefits of natural light for chickens?

Chickens show more activity, a wider range of natural behaviours, and better mental wellbeing

Natural light provides brighter daytime lighting and a fuller spectrum of visible light, including UV wavelengths, unlike artificial lighting. This is why natural light is the single most important environmental factor for increasing activity in broiler chickens..[36,37,54,87] Natural lighting can significantly reduce the number of chickens resting and lying during the daytime,[36,37,54,87] while increasing the percentage of time chickens spend active by 30% in industry reports.[87] Research has shown natural lighting in broiler barns can increase the time birds spend standing, foraging, exploring, ground pecking, eating, and drinking walking, and running during daylight hours.[37,88,89] Fast-growing broilers provided with natural light from roof windows and enrichments (substrate bales, perches, and metal chains) were observed resting less and walking, running, and exploring significantly more than flocks housed in artificially-lit barns both with and without the added enrichments.[88] A 2013 UK commercial study also showed more frequent idling in fast-growing Ross chickens housed with windows than artificial light.[89] Idling describes birds that show temporarily heightened alertness, with their heads upright and fully eyes open, before transitioning to another behaviour. More active birds in natural lighting are expected to show more idling bouts as they more frequently transition between a wider range of behaviours (Table 3).

Table 3. The effect of natural light on the average percentage of fast-growing Ross broiler chickens performing different behaviours every week during instantaneous scans of six randomized sampling quadrants of each commercial barn. The behavioural scans were taken on 16 commercial flocks (8 with and 8 without natural light) on two farms in Northern Ireland (UK) with each flock containing ~23,000 birds stocked at <30 kg/m^2. Natural light entered through double-glazed glass windows (46 windows per barn), which provided an average daytime light intensity of 85.2 lux and UV light levels of 3.37mW/cm^2.[54]

Behaviours	Treatment	
	With natural light	Without natural light
Lie	66.65%[a]	70.82%[b]
Stand	33.35%[a]	29.18%[b]
Rest	21.34%[a]	29.58%[b]
Ground Peck	10.34%[c]	7.55%[d]

[a,b]Different superscripts within a row represent a significant difference of $P < 0.05$
[c,d]Different superscripts within a row represent a significant difference of $P < 0.01$

In addition to reducing bird inactivity, a 2021 Brazilian study showed broilers with natural light entering through open-sided barns had a higher incidence of positive emotional states, suggesting improved mental wellbeing.[90] Even under poorer environmental conditions during the winter months, including reduced ventilation and higher ammonia levels, the flocks with natural lighting scored as inquisitive, confident, interested, lively and positively occupied, when evaluated through QBA. In contrast, the flocks housed in artificial lighting scored higher on negative emotional states, such as apathetic, dull, lethargic, disturbed, fearful and distressed.[90] Similarly, QBA showed chickens in open-sided, naturally-lit Brazilian barns were less frustrated and distressed, and more comfortable, content, energetic, and positively occupied than broilers reared in artificially-lit barns in Belgium.[91] However, better environmental conditions amongst Brazilian farms in this study, including lower stocking densities (Brazil: 27.55±0.90 *vs.* Belgium:39.97±0.92 kg/m^2) and flock sizes (12,859±848.3 *vs.* 20,054±1957.6 birds per flock), compared to the Belgian farms may also have contributed to improved positive emotional state of these flocks.

Chickens show higher use of environmental enrichment

Several studies have shown providing natural light in commercial barns leads to higher use of enrichments by chickens, including straw bales, wood shavings bales, metal chains, and perches.[88,89] Chickens housed with natural light spend significantly more time gathered around or perched on top of straw bales during daylight hours than chickens provided straw bales in artificially-lit barns.[89] Given chickens' vision evolved in natural sunlight, providing chickens with natural lighting is thought to improve their vision indoors leading them to engage more with their environment, including with the enrichment provided. Plant matter is known to reflect UV light, so the UV reflectance of straw in natural light may further attract the chickens. Natural light can also create a subtle variation in light intensity across the barn during daylight hours. This can stimulate birds to use different areas of barn, based on how brightly lit, for different behaviours during the daytime. For instance, chickens with natural lighting may instinctively seek out the darker, sheltered areas alongside the substrate bales to rest and preen with protection from predators.[89]

Chickens show improved leg health, fewer breast lesions, & cleaner plumage

I. Improved leg health and walking ability

Natural lighting from windows has been shown to improve the leg strength and physical mobility of commercial flocks of fast-growing broilers. Chickens housed under natural light stood for significantly longer in a latency-to-lie test (16.4 seconds), reflecting greater leg strength, than birds from artificially-lit barns (12.9 seconds, $p < 0.001$).[89] Broilers in naturally-lit barns also had lower average flock gait scores both with (1.02) and without straw bales (1.00), meaning the flock had a better walking ability overall, than chickens housed in artificially-lit barns with (1.09) or without bales (1.28, $p < 0.001$).[89] Improved leg health and mobility likely reflects the higher activity levels of chickens housed with natural light throughout rearing. These birds spend more time walking, running, and standing - and less time lying and resting, which leads to improved skeletal and muscular development for the legs of these growing chickens.

II. Fewer breast lesions & cleaner plumage

Research suggests broilers in open-sided barns with natural lighting in the spring and summer have cleaner plumage and less severe breast lesions when compared to fully enclosed, artificially lit barns.[38,91] For instance, a 2015 study observed Brazilian flocks in open-sided barns with natural lighting in the spring months had cleaner plumage and more, but less severe breast lesions, than broilers reared in fully-enclosed, artificially-lit barns in Belgium.[91] Yet it is important to acknowledge the improvements in these animal-based welfare measures are confounded by season and its impacts on the indoor air quality and litter dryness. For example, a different 2015 study showed chickens in open-sided barns in Brazil had more breast, abdominal, and hock burn lesions and dirtier plumage scores during the winter months than fully enclosed barns in this region. This highlights the need to tailor management by season to ensure good indoor ventilation year-round in all barn set-ups, including open-sided barns in subtropical climates.[90]

Chickens prefer natural over artificial lighting when given the choice

A 2021 Brazilian study showed when given the choice, Cobb 500 broilers spent significantly more time throughout the daylight hours under brighter natural lighting (average 545.5 lux) from windows than dimmer artificial LED lighting (32.4 lux).[37] When averaged from 9-36 days of age, the windowed areas had 67.1% of chickens during the daytime compared to 32.9% under LED lighting (Figure 6).[37]

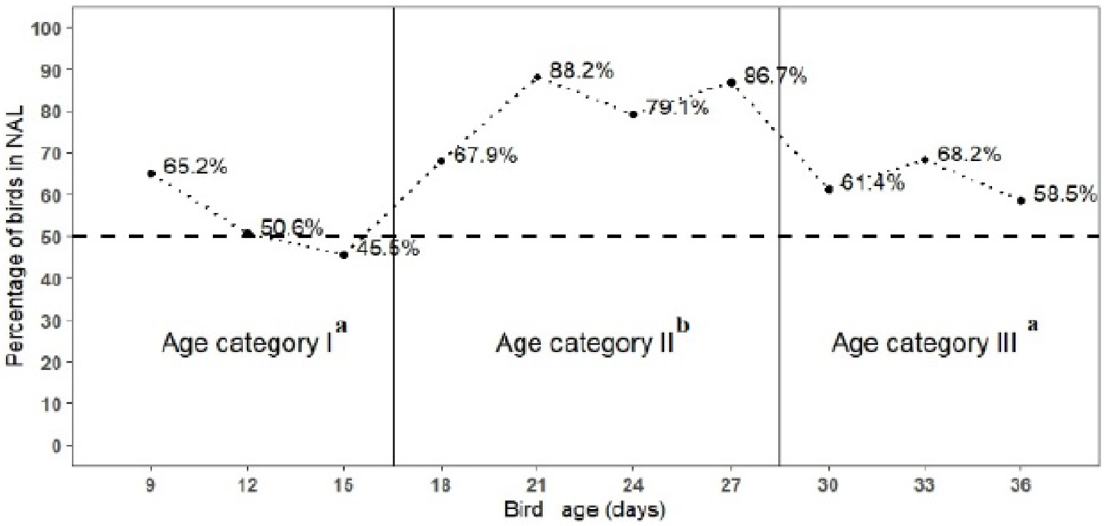

Figure 6. Percentage of Cobb 500 broiler chickens observed during daytime hours in the side of the barn lit with natural light (NAL; average daytime level at 1000 and 1500h: 459-655 lux) or artificial light (average daytime level at 1000 and 1500h: 23-42 lux). Chicken occupancy was measured at three different broiler ages (age category I: 9-15 days old, age category II: 18-27 days old, age category III: 30-36 days old) in a broiler barn in Paraná, Brazil. Age categories with different superscripts differ significantly ($p<0.05$) (Source: Sans *et al.,* 2021a).

Improved litter condition reduces the risk of painful contact dermatitis lesions

Research and industry practice have reported drier litter conditions when chickens are housed with natural lighting.[54] Higher bird activity during rearing in natural-lit barns results in greater aeration of the litter, which quickens the evaporation of moisture from the litter. Drier litter can reduce the risk that chickens develop hock burn or footpad dermatitis lesions. Birds that are more active under natural lighting also spend less time resting on the litter, which reduces the time their hocks are in contact with the litter and may lower the risk of hock burn lesions.[54] There are additional benefits of natural light that can improve the economics of broiler chicken production. For instance, drier light quality reduces the need for frequent litter replacement during grow-out. This has been associated with increased worker productivity and higher worker satisfaction in broiler barns that utilize natural light.[38,54,91]

Methods for providing natural lighting in broiler barns

In practice, natural light is commonly provided in broiler barns through the following methods: windows or transparent panels on the side walls or roof of the barn, solar tubes on the barn roof or side walls, or open-sided barns with curtains and natural ventilation. These light sources often have covers, curtains, slats, or screens to control the entry of natural light. Barns that are open-sided or with side wall windows often close these light entry points overnight to ensure complete darkness during the dark period.

I. Windows:

Although roof-mounted windows can provide more uniform light distribution across the floor area, side wall installations are recommended for broiler barns due to their ability to create a more dynamic and heterogeneous lighting environment, which better replicates outdoor light conditions and may be more beneficial for supporting natural behavioural patterns in broilers. Windows should be made of reflective or low-emissivity glass to maximize the amount of visible light and UV-A wavelengths available to the chickens, while minimizing the entry of solar heat indoors. For existing barns, windows should be retrofitted into the roof or side walls, covering at least 3% of the total floor space. For new barns, window openings should cover at least 5% of the total floor area. In regions where heat stress is a concern, windows should be made of thick, double-glazed glass and fitted with coverings such as shutters, blinds, slats, or curtains to limit light entry during the hottest parts of the day. Figures 7 to 9 show examples of various ECC-compliant window installations that allow natural light to enter commercial broiler chicken barns in Europe.

<u>The composition of windows</u>

i. Window materials

The material used for the windows requires consideration to minimize heat loss or entry into the barn (Table 4). All types of glass block the entry of UV-B wavelengths but transmit visible light and UV-A wavelengths. However, the amount of UV-A light (315-400nm) transmitted through glass varies based on the type of glass and its thickness.[37,54,92–94] Tinted (or heat-absorbing), reflective, and low emissivity (low-E) glass have added coatings to minimize the entry or loss of heat, but consequently also reduces the transmission of visible and UV-A light wavelengths. Windows for natural lighting of barns should not be made of laminated glass, UV-blocking coated-glass, or polycarbonate plastic. Given these materials block ≥99% of UV-A light, the chickens would not experience the benefits of a fuller light spectrum that includes UV wavelengths (Table 4).[92,93]

ii. Thickness of windows

The thickness of the window materials can also impact the percentage of visible and UV wavelengths from natural light that can enter. Thicker glass (~12 *vs.* 6mm) and polycarbonate plastic windows are used for commercial applications to provide better insulation. However, this consequently reduces the entry of visible and UV wavelengths (Table 4).

For glass windows, the number of panes (sheets) set in the window frame can greatly affect the insulating properties of the window. For instance, single pane glass may cause temperature increases in the house and cause hot sunspots. Double-glazed glass has two panes of glass mounted with a small space in between, which reduces the solar heat entering by ≥10% without substantially reducing the transmission of visible (~6-8% less) and UV-A light (~15% less) through the windows (Table 4).[93]

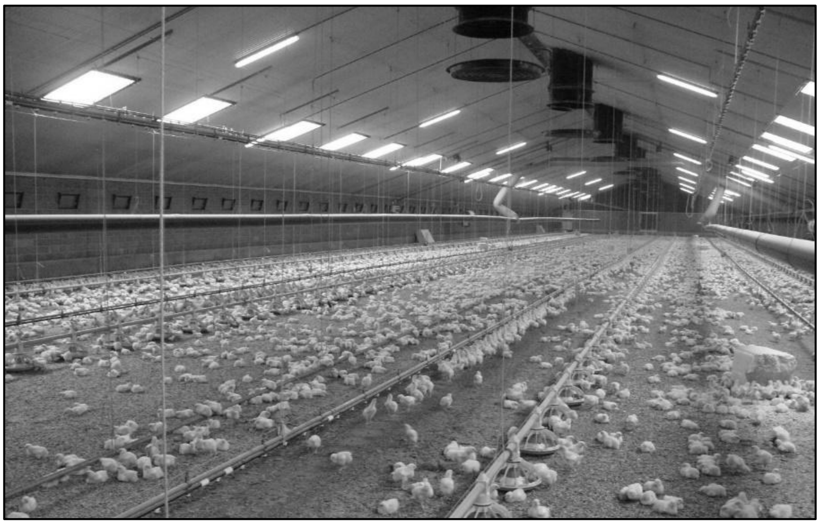

Figure 7. A 1515m^2 (approx. 18 x 85m) commercial broiler barn in the Netherlands equipped with two rows of 21 windows (total 42 windows) in the roof to allow natural light to enter. Each roof window measured 1.25m^2, providing a total window area equalling 3% of the total floor space. Artificial lights on the roof are available to supplement daytime natural lighting as needed (Source: de Jong & Gunnink, 2019).

Figure 8. Label Rouge chickens grown in a broiler barn in France with natural light provided through glass windows on the side walls. Supplementary artificial lighting is available on the barn roof, and the chickens are provided with straw bales indoors and free-range access (Source: Hans Siemes).

Figure 9. Label Rouge slow-growing broilers in a free-range barn in Brittany, France. Natural light is provided through a row of windows along the edge of the roof. During the daylight hours, the pop holes providing access to/from the outdoor range also allow for the entry of natural light (Source: Farmers Weekly).

Table 4. Comparing the maximum amount of visible light, UV-A wavelengths, and solar heat transmitted by different window materials used for commercial architecture applications[37,92,93,95]

	Clear glass	Tinted (heat absorbing) glass	Tempered glass	Laminated glass	Reflective glass	Low emissivity (low-E glass)	UV-blocking glass	Polycarbonate plastic
Total thickness of the material (mm)	3-6*	6-12*	4-8	6-12*	12*	9-12*	6-12*	0.8-4
% of visible light transmitted	82-90%	40-56%	73-79%	79-80%	19-43%	68-71%	67-69%	20-90%
% of UV-A transmitted	57-72%	20-33%	28.4-54.5%	0.5%	17-25%	20-28%	0.1-0.2%	0%
% of solar heat transmitted**	72-83%	53-52%	<50%	58-63%	13-24%	32-36%	32-34%	16-86%

*Values reported are for two double-glazed panes of 3mm (or a 3mm & 6mm) glass and two 6mm glass panes; **Transmission of solar radiatio

iii. Size and placement of windows

Windows must be of a sufficient size and installed within the structure of the barn to ensure enough natural light can enter the barn to meet the average ≥50 lux daytime light levels throughout the house, without impacting the internal temperature or causing sunspots (Table 5). To meet the ECC natural light requirements, it is recommended retrofitting at least 3% of the total floor space as windows on existing barns, and 5% on new broiler houses.

During installation, windows should be sealed appropriately to minimise heat loss from the house and prevent draughts. Windows should be placed along both sides of the barn walls or roof to allow for the even distribution of natural light throughout the house. However, barns near roadways should avoid placing windows on walls or use solid coverings to block bright bursts of light at night from cars driving on the road that could startle the chickens.

If windows are being retrofitted into poultry housing, the location of vents and ventilation system may affect window placement. Care should be taken to ensure natural light entering the barn is diffuse so there are no areas of extreme light or dark. Extreme light contrasts within the barn may cause chickens to crowd in these areas leading to smothering, which can result in injuries and/or mortalities. Trees planted along the outside of the building can also assist in reducing high levels of direct sunlight.

iv. Window coverings

Shutters, blinds, slats, or shade cloth can be used on or within wall or roof-mounted windows to control light into the barn when sunlight levels are high (Table 5).[96] For instance, if the sun is high at a certain time of day along one side of the barn, shutters or blinds can be used on manage the amount of light entering through the windows on that specific side of the barn and prevent sunspots. Motorized coverings can be especially useful for controlling the entry of sunlight through roof windows. Automated window coverings use sensors to detect changes in indoor light levels. These systems can fine tune the percentage the windows are covered to more closely control the amount of natural light entering the houses and the indoor temperature.

II. Solar tubes

Solar tubes are light tubes which capture light via an acrylic dome from the roof of a building (Figure 10). The light is transferred by means of a pipe, lined with reflective material, to a diffuser inside the building. Solar tubes are an alternative method for providing natural light when windows cannot be installed due to ventilation systems, or when extremes in climatic conditions mean that temperature conditions do not allow for windows - for instance, in locations with hot weather climates. Solar tubes present several benefits: a bright and diffuse distribution of light across the barn, good insulation value, low maintenance, easy to reduce/darken the entry of light from each solar tube using motorized daylight dimmers, can be fitted on any type of roof, and can be easily installed alongside solar panels on roofs.

Solar tubes allow 92% of visible light to pass through but completely block UV-B wavelengths. The amount of UV-A entering the house with these systems is ≤1.5%.[97] However, light tubes use a fraction of the required glazed surface area normally associated with conventional windows which can improve the structural, thermal, acoustic and, in some cases, ventilation properties of buildings. Solar tubes can be fitted into the side or the roof of the building. Solar tubes in the roof of a barn deliver a higher degree of diffuse light uniformity across a much greater area that what can be achieved by traditional windows. This is because the position of solar tubes in the roof is less affected by the building's orientation. The number of light tubes installed will impact the daytime light levels than can be achieved with the house. The 3% floor area equivalence for windows cannot be used for light tubes and liaison with a light tube distributor is required to ensure enough systems are fitted to achieve the ≥ 50 lux ECC lighting requirement.

Figure 10. Fourteen solar tubes installed in two rows on the roof of a Dutch broiler barn. (a) The first image shows an external view of the broiler barn with the solar tubes installed on the roof. When this image was taken, the outdoor light intensity on this cloudy day in the Netherlands was reported as ~1200 lux. (b) The second image shows the inside of the broiler barn lit by the entry of natural light through the solar tubes (Source: Poultry Daylight UK).

III. Curtain-sided and open-sided barns

Curtain-sided and open-sided barns typically consist of a lower solid wall to prevent birds from moving out of the barn, with the top side of the wall covered in mesh wire, or a thin, translucent plastic covering (Figure 11). When the top side is only mesh-covered or has movable curtains, air can flow directly into and out of the barn for natural ventilation. Both the mesh and plastic coverings prevent other wildlife (for example, wild birds) from entering the indoor barn environment. These houses will often have shade cloth, slats, or a single/double row of curtains on each side wall that can cover the mesh or plastic top openings to better control the entry of light and prevent the loss or entry of heat depending on the outside conditions. The thickness, insulation value, and colour of the curtain or cloth material can be selected to fine-tune the entry of light and air into the broiler house.[90,98–100] In comparison to windows or solar tubes, curtain-sided barns allow in the fullest spectrum of natural light, including UV-A and UV-B wavelengths, with minimal distortion even when permanent thin plastic curtains are in place.[37,38,90] Additionally, curtain-sided and open-sided barns allow the entry of fresh air, providing chickens with a truly natural environment to best support their welfare. Curtain-sided and open-sided barns may also have artificial sources of lighting installed to be used for supplementary light indoors as needed. However, this type of barn structure can be challenging to manage in regions with consistently very cold (<10°C) or hot (>30°C) weather. The lack of solid insulation over such a long area of the curtain-sided and open-sided barn's structure can cause considerable challenges for maintaining a comfortable environment for the chickens in these regions. In barns without permanent curtains, natural ventilation can help to cool the birds and improve the air quality indoors during the hotter months but also allows strong solar rays to enter causing the birds to show signs of heat stress, such as painting. In colder temperatures, the moveable curtains are often rolled down partially or fully to maintain heat inside the barn. The humidity and ammonia concentrations can build up within the barn without air flowing through the wall openings. Similarly, the layout of all curtain-sided barns, with or without permanent curtains, must be designed with supplementary artificial ventilation. This includes well-positioned fans, air inlets, fogging systems, sprinklers, and evaporative cooling pads to maintain good environmental conditions within the house year-round.[90,98,99]

Figure 11. Two types of curtain/open-sided commercial broiler barns: (a) a chicken barn in Uganda with both upper and lower curtains on the side walls for control over the entry of natural light and temperature indoor (Source: Poultry Farming Uganda), (b) a flock of slow-growing broilers inside a Brazilian chicken house with curtain siding to allow for the entry of sunlight and natural ventilation (Source: Daniel Azevedo).

Table 5. An overview of natural lighting set-ups in commercial broiler operations

Method for providing natural light	Total size of each light inlet	Number of light inlets per barn	Natural light inlet placement on the barn	% Natural light inlet of the total floor space
Windows composed of double glazed, toughened glass (*e.g.*, United Kingdom)[54]	1.32 m^2	46 (23 on each long wall)	1.5 m high along both long side walls	4.6%
Windows composed of layers of transparent corrugated sheets and polycarbonate sheets with black out slats (*e.g.,* Netherlands)[88,96]	1.25 m^2	42 (21 per roof row)	One row on each long side of the roof	3.5%
Windows composed of 8 mm colourless, tempered glass (*e.g.,* Brazil)[37]	1.19 m^2	8 on one long wall	One row on one long side wall	31.6%
Curtain-sided with permanent translucent coverings (*e.g.,* USA)[100]	89.04 m^2	1 on each long wall	Top part of both long side walls	10%

IV. Supplemental artificial lighting

To meet the ECC lighting criterion, natural lighting should be the primary source of light used to achieve an average of ≥50 lux of daylight across the barn. However, artificial lighting may be used to complement natural light sources, when natural lighting is unable to meet an average daytime light intensity of ≥50 lux. For example, cloudy, rainy, or snowy weather conditions may lower the amount of natural light entering the house and be insufficient to meet the ≥50 lux daytime light intensity without supplementary artificial lighting. During daytime hours, artificial lighting in the barn should be flicker-free, provide an average intensity of at least 50 lux, and equivalent to natural sunlight in terms of frequency, including UV-A wavelengths. When providing supplementary artificial lighting inside commercial chicken barns, several options are available, including non-LED compact fluorescent lights (CFLs), light emitting diode (LED) lights, and LED lights combined with ultraviolet (UV) light (UV-LED). Non-LED CFLs have traditionally been used in poultry houses, but they tend to emit more heat, consume higher amounts of energy, and have a shorter lifespan compared to LEDs. In contrast, LED lights are increasingly favored for lighting chicken houses as LEDs provide a fuller spectrum of light and are more energy-efficient, last longer, can be dimmed without impacting bulb longevity, and generate less heat, which can help maintain the optimal barn temperature for the chickens.[101] A newer advancement in poultry lighting is the combination of LED lights with UV light (specifically, UV-A light). While the upfront cost of LED + UV-A light systems may be higher, the potential benefits for chicken welfare, including better gait scores, fewer mortalities, and less fearful birds, can make them a worthwhile investment.[102,103] LED-UV lighting best replicates the full spectrum of visible light provided by natural sunlight. Additionally, these systems can be programmed to reflect the changes in natural light wavelength (colour) composition throughout the day.

The light properties of different light sources within a barn

I. Light intensity[7]

	Windows	Solar tubes	Artificial light: non-LED compact fluorescent lights (CFLs)	Artificial light: light emitting diode (LED) light[104]	Artificial lighting: LED + UV light[102,105]
Type of light	Direct and diffuse	Diffuse light: no risk of sunspots	Indirect and diffuse	Direct but can be diffuse across large area if correct diffuser applied	Direct but can be diffuse across large area if correct diffuser applied
Heat transmission	Possible – in and out. Risk of heat stress, especially in hot countries	No risk - more control over the environment. Particularly useful for hot countries	Possible – CFLs release 20% of energy as heat	Minimal risk– LEDs emit no to very little infrared radiation (heat)	Possible – More than LEDs, as some UV is converted and emitted as heat
Amount of light transmitted	Potential to transmit 80% of light	Potential to transmit 92% of light but work best in direct sunlight and less well in overcast conditions	Typical CFLs transmit ~55 to 75% of electrical energy into light	Typical LEDs transmit 80-95% of electrical energy into light	LED + UV bulbs may only convert 15-25% of electrical energy into light[105]
Light distribution	Placement of windows along the sides of the barn can lead to gradients in light intensity between the edge and centre of the barn and light intensity can be more affected by position of the sun	Placement of solar tubes throughout the barn ensures an even spread of light in the barn. Capture light from the roof of the barn so less dependent on the position of the sun	Placement of CFLs throughout the barn ensures an even, diffuse spread of light throughout the barn	Placement of LEDs throughout the house, and use of appropriate diffusers, required to achieve diffuse lighting across barn	Placement of LEDs + UV lights throughout the house, and use of appropriate diffusers, required to achieve diffuse lighting across barn

Variation	Potential to allow natural variation in light intensity due to daily, seasonal, or climatic conditions	Potential to allow natural variation in light intensity due to daily, seasonal, or climatic conditions	CFLs can be dimmed to change light intensity but will be a uniform change across barn for bulbs on the same circuit. Regularly adjusting the bulbs leads to quicker burn out	LEDs are easier to dim than CFLs. Dimming will result in a uniform change in light intensity across the barn unless individual LED lights are on different electrical circuits	Like LEDs, UV-LEDs are easy to dim. Dimming will result in a uniform change in light intensity across the barn unless individual LED lights are on different electrical circuits

II. Wavelength

	Windows	Solar tubes	Artificial light: non-LED compact fluorescent lights (CFLs)	Light emitting diode (LED) light	LED + UV light
UV-B Light	Block 100% UV-B	Block 100% UV-B	Emit a small amount of UV-B[106–108]	Typical LEDs block 100% UV-B[107–109]	Dependent on UV bulb type. For commercial chicken barns, LED + UV-A bulbs have been applied with no UV-B emission[102,103]
UV-A Light	Block 25% UV-A[110] – but penetration into the centre of the barn depends on windows, window coverings, and structures in the barn	Block 98.5% UV-A[111] – should ensure an even spectrum throughout the barn even if limited	Emit a small amount of UV-A[106–108]	Typical LEDs block 100% UV-A unless specific LED + UV-A bulb[107–109]	Dependent on UV bulb type. For commercial chicken barns, LED-UV-A bulbs release UV-A wavelengths[102,103]

Variation	Potential to allow natural variation in wavelength due to daily, seasonal, or climatic conditions	Potential to allow natural variation in wavelength due to daily, seasonal, or climatic conditions	Not possible	Potential to change light spectrum emitted by bulbs through the addition of gels, r lenses, or films	Potential to change spectrum of light by bulbs emitted but only through the addition of gels, lenses, or films[102]

III. Duration

	Windows	Solar tubes	Artificial light (non-LED)	Light emitting diode (LED) light	LED + UV light
Variation	Potential to allow natural and gradual variation in photoperiods and seasonal changes	Potential to allow natural and gradual variation in photoperiods and seasonal changes	Potential to dim lights for gradual changes in photoperiod and seasonal changes but will be uniform across the barn and lead to quicker bulb burn out	LEDs are easy to dim for gradual changes in photoperiod and seasonal changes. Dimming will result in a uniform change in light intensity across the barn unless individual LED lights are on different electrical circuits	LED + UV lights are easy to dim for gradual changes in photoperiod and seasonal changes. Dimming will result in a uniform change in light intensity across the barn unless individual LED lights are on different electrical circuits

Additional guidance on providing ECC-compliant natural lighting indoors

I. Systems in hot areas

In regions prone to hot and/or humid weather, solar tubes installed on the roof of the chicken barn offer the highest insulation value from the outdoor conditions for fully indoor housing systems. If the producer prefers to use windows, windows on the side walls should be positioned to avoid the entry of the strongest direct light rays during the middle of the day to reduce the possibility of overheating the barn. Windows should be made of thick, double-glazed reflective or low-emissivity glass and be installed with coverings (for example, shutters, blinds, slats, curtains, or an opaque surface film) to reduce or diffuse the entry of light during the hottest parts of the day (Table 4). For open-/curtain-sided barns, it is recommended that the long axis of the barn is built on an east-west orientation to avoid direct sunlight on the side walls of the house. Open/curtain-sided houses should also be <10 m in width, with at least 12 m between barns, and built on higher ground *vs.* valleys for better air movement to ventilate the chicken barns.[98]

II. Systems in areas with no sunlight during the winter

In northern regions where at least one rearing cycle each year is during a seasonal period without direct sunlight, artificial sources of light that mimic the qualities of natural light are permitted to achieve the ECC lighting criterion.

The artificial light source <u>must</u> provide:

- **(a) a minimum of 50 lux during the light period,**
- **(b) a full spectrum of visible light, including UV wavelengths,**
- **(c) and should be free of flickering.**

Prior to the introduction of LED light bulbs, artificial light could only change the intensity level of the light (lux) provided in chicken barns. LED technology now allows the lighting to be fine-tuned and adjusted according to the spectra emitted (colour, UV), time of day, and different functional areas of the barn.

Norsk Kylling, a chicken producer in Norway operating with ≤6 hours of dim daylight during the winter months, has installed a LED + UV-A lighting system to consistently provide a full spectrum of bright light in their barns each day, which mimics the properties of natural light.[112] This improved lighting system led to a reduction in mortalities (2.21 *vs.* 2.44%), footpad dermatitis (4.3 *vs*. 9.3%), and carcass rejections at slaughter (0.56 *vs.* 0.72%) in comparison to flocks reared under artificial lights without added UV.

III. Free-range systems

For free-range operations that provide chickens with outdoor access, natural light must still be the primary source of light indoors and the minimum light intensity of 50 lux must be maintained in the barn during the light period (Figure 13). This ensures that all chickens within the flock have a full spectrum of bright light each day to support good welfare even while indoors during daylight hours. Bright daytime lighting indoors is critical given chickens in free-range systems typically do not have outdoor access for the first third or half of their lives (approximately 3-4 weeks of age) until they are fully feathered for thermoregulation concerns. Free-range flocks may also be restricted from accessing the outdoors during extreme weather conditions or disease outbreaks (*i.e.,* government biosecurity mandates to prevent the spread of avian influenza).

Figure 12. Hubbard JA757 slow-growing broilers in a RSPCA free range barn in the United Kingdom. Natural light is provided through glass windows, as well as the pop-holes to/from the outdoor range, on the side barn walls (Source: Compassion in World Farming).

IV. Systems with wintergardens

Wintergardens (also called verandas) offer broiler chickens access to natural light, fresh air, and additional space for exploration within a sheltered environment, which can remain usable even during adverse weather (Figure 13). In 2023, the European Food Safety Authority (EFSA) issued updated guidance based on the latest scientific evidence, recommending that all broiler chickens have access to a covered wintergarden by 14 days of age.[113] Unlike other enrichments that broilers may lose interest in over time, wintergardens show more consistent and continued use. For instance, a 2025 study found that slower-growing Hubbard Redbro broilers increased their use of wintergardens from an average of 25 birds at 22 days of age to over 200 birds by day 37.[114]

To ensure adequate natural light, at least one of the long sides of the wintergarden should be open and covered only with mesh or netting. Chickens should be allowed access to the wintergarden for at least 8 hours of daylight daily, or for the entire daylight period in regions or seasons with shorter days. Pop-holes (maximum 25 cm high & minimum 2m wide per 100 m^2 of indoor barn space) with ramps should be used to allow movement between the barn and the wintergarden.[113,115] While these pop-holes may let in some natural light, they cannot serve as the primary light source for the indoor barn. In regions with frequent overcast conditions, alternating transparent and non-transparent roof tiles can help brighten the wintergarden while also creating a more natural gradient of light throughout the space.[115]

Like free-range systems, access to the wintergarden may be restricted during the first third or half of the broiler's life, or temporarily during extreme weather or disease outbreaks. Instead, barns must use dedicated methods, such as windows or solar tubes, to provide natural light, which must remain the main source of indoor lighting, and maintain a minimum light intensity of ≥50 lux during the light period. Further guidance for designing wintergardens for broiler barns to maximize bird use is available at the European Union Reference Centre for Animal Welfare – Poultry SFA.[115]

Figure 13. A wintergarden (or veranda) for a broiler chickens flock (breed unknown) attached to barn under the German Land Bauern Hähnchen certification. The wintergarden has one of the long sides open allowing the entry of natural light, and there is ample straw flooring in the wintergarden and straw bales as additional enrichment (Source: REWE 2025).

V. Systems with dark brooders

Young chicks that are less than one week old tend to avoid direct light within the barn and can be at risk of smothering in the shaded areas, for instance, near the side walls of the barn.[116] During the first week of rearing, the use of curtains, slats, or coverings over natural light sources, such as windows, is recommended to prevent sunspots on the litter. The entry of natural light into the barn should be minimized, especially if the daytime sunlight is strong, to ensure the indoor lighting remains diffuse across the barn. The use of dark brooders is encouraged with or without supplementary heating, such as the **'motherhoods'** in the Dutch Windstreek system (Figure 14).[117] Dark brooders provide covered, dimly lit areas on the littered floor for broiler chicks to rest undisturbed during the first few weeks of life, which simulates the safety and warmth of being underneath a mother hen.[117,118] The minimum 50 lux light intensity is not required underneath the brooders to meet the ECC criterion. Some producers may also choose to close natural light inlets and use artificial lighting during the first seven days before switching to natural lighting for their broiler flocks.

Figure 14. The ‘motherhoods’ set-up provided in the Dutch Windstreek barn set-up that provide a warm, dimmer area for the chickens in the house throughout the grow-out period. These ‘motherhoods’ act as dark brooders for young broiler chicks that are hesitant to rest in the open, more brightly lit spaces in the barn. The ‘motherhoods’ contain infra-red heaters, LED lighting, a water line, and perch (Source: Compassion in World Farming).

Conclusion

Providing chickens with natural lighting, in compliance with the ECC, can greatly benefit the health and welfare of broilers on commercial farms. Research shows chickens have a highly developed visual system, and broilers provided with natural light indoors are significantly more active and show a wider range of natural behaviours indicative of positive welfare. Unlike artificial light sources, natural lighting produces a gentle natural gradient of daytime lighting across chicken houses. Natural light sources also inherently provide a fuller spectrum of light (including UV) that better supports the health and welfare of commercial chickens. Windows are currently the most common method for providing natural light in commercial broiler barns, while solar tubes can be more adapted to areas prone to hotter environmental conditions. Open- or curtain-sided barns are ideal for temperate climates, as these houses provide chickens with unfiltered sunlight and natural ventilation. Research shows broiler chickens prefer a natural gradient of light, choosing the desired light intensity for the behaviour they are motivated to perform. Today, most commercial chicken barns are predominantly dark throughout the day (≤20 lux). To best support broiler welfare, all barns must offer enough brightly lit space (*i.e.,* ≥50 lux over 80% of the littered floor space) during daylight hours for every bird in the flock to be active and express important species-specific behaviours, such as foraging and locomotion. Consumer demand continues to grow for higher-welfare products, including chicken, so it is essential for food businesses to prioritize incorporating ECC-compliant sources of natural light when building new or retrofitting existing barns for broiler chickens.

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