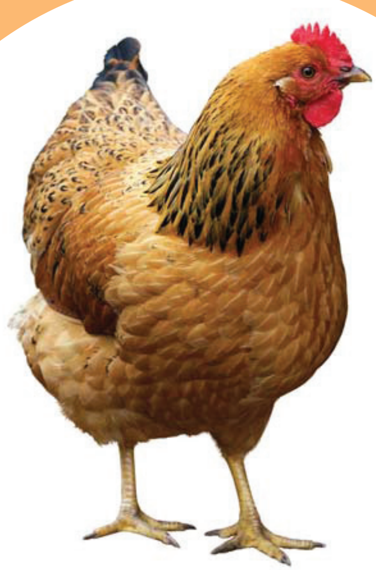
THE SCIENCE OF POULTRY LIGHTING. A BIRD'S EYE VIEW.

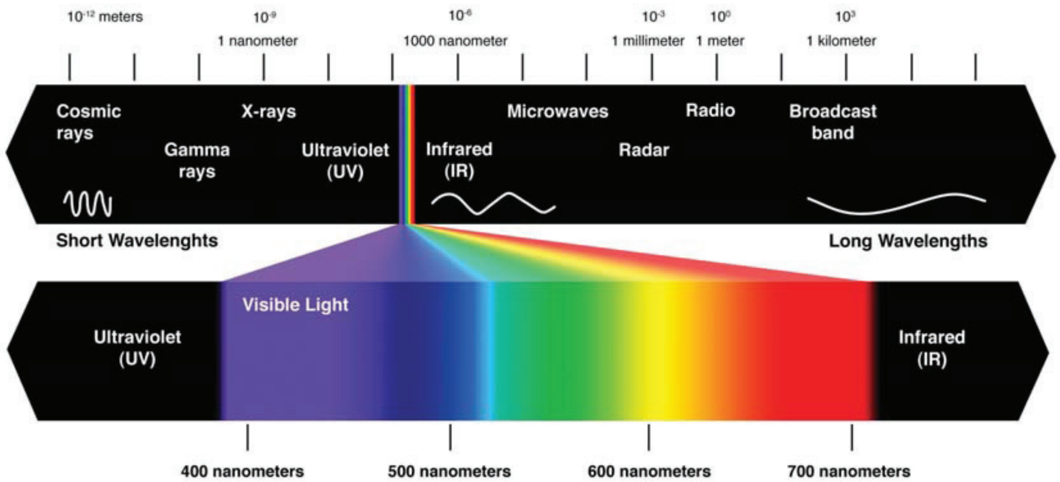
The light we see affects our mind and a wide variety of metabolic processes within our body. Eyes are undeniably one of our most important organs. It is where light penetrates the retina and stimulates multiple biological functions. The light we perceive is part of the electromagnetic spectrum our eyes can detect, known as the visible spectrum.

The same is true in animals, including poultry, but with one significant difference. *The spectral sensitivity and visible spectrum of poultry, or what they actually see, is not the same as humans.* It is why chickens or turkeys may behave differently under the same intensity light from two different sources that look identical to us. Chickens and turkeys absorb light through their eyes in ways humans don't. In addition to retinal light perception, poultry can sense light through the pineal gland commonly called the "third eye" situated on the dorsal surface of the brain. The avian pineal gland is particularly involved in the control of circadian rhythms and sexual activity. A circadian rhythm is a 24-hour cycle in the biochemical, physiological and behavioral processes of all animals.



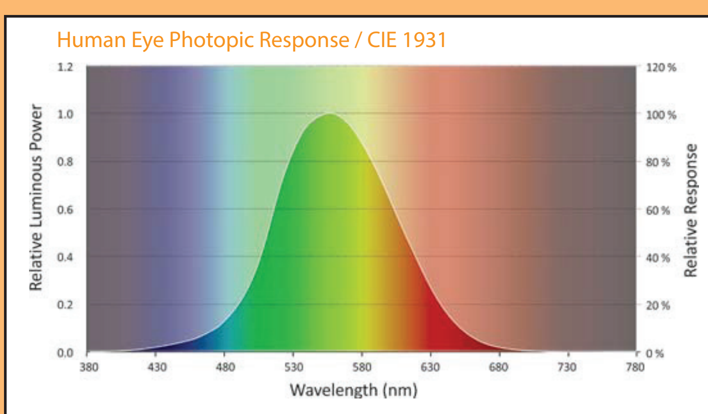
The visible light spectrum

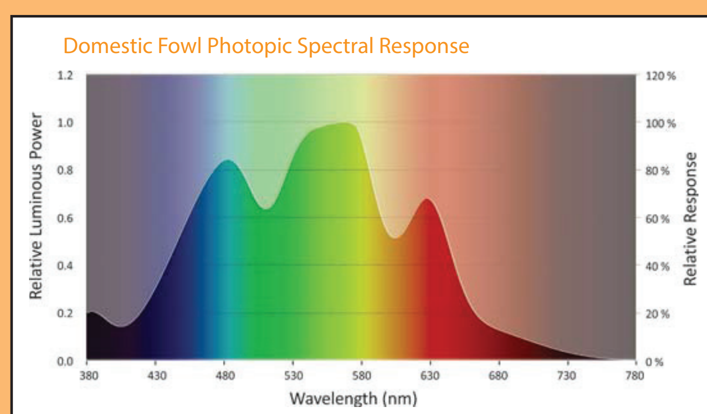
The visible spectrum is the portion of the electromagnetic spectrum that is visible to, and can be detected by, the animal eye. A typical, healthy human eye will respond to wavelengths from about 400nm to 750nm. Different wavelengths indicate colors in the visible spectrum ranging from violet 400nm to 750nm deep red color with a significant sensitivity peak at 555nm green. As bizarre as it may sound, there is no white or natural light "wavelength". Natural white light is a combination of different color wavelengths. Think of how light traveling through a glass prism turns into visible monochromatic colors of light called color spectrum. Now mentally reverse the process where the same colors combine and turn into visible light where we don't discern the individual colors – even though they exist and play a role in how we feel, act, and what happens within our bodies.



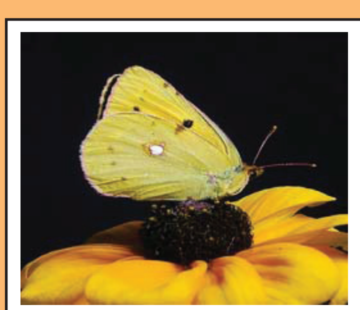
Sensitivity to different colors

The graphs below show photopic (day vision) relative spectral sensitivity of the human eye and the domestic fowl eye. Both graphs show a similar sensitivity peak in the green spectrum. This is so humans and poultry can see well in the available light under green forest canopies, which was and is, part of the primary habitat of both. Poultry, however, are considerably more sensitive to red light and blue light and can see UV light (that humans do not). The graphs also clearly indicate that the relative photon catch is different for humans and poultry resulting in a very interesting fact: *perceived light intensity is considerably higher for poultry.* Pictures below the graphs show how colors are perceived by humans compared to an approximation of domestic chicken vision with the emphasis on near UV reflections.





Data source: "Spectral sensitivity of the domestic fowl (Gallus g. domesticus)" N. B. PRESCOTT AND C. M. (1999)



The effects of artificial light

There are several aspects of artificial light important to poultry producers, including these of some significance:

1. **Spectral composition:** The distribution of light wavelengths (indicates how much of each color is present)
2. **Photoperiod:** The number of hours of light and dark in a 24-hour period
3. **Light intensity:** The total amount of luminous power produced in the visual part of the light spectrum

Using an inappropriate artificial light, or simply improperly measured light intensities, will result in the illuminance (footcandle, lux) being too high or too low. The consequences of inappropriate lighting may affect health, production and welfare of your flock due to the abnormal light-induced biological responses. While there are guidelines for the optimum light level for domesticated species, recommended illumination levels are based on standard incandescent illumination for humans that are calibrated for the human photopic sensitivity curve (CIE 1983). No account is made for the species-specific differences in spectral sensitivity for birds nor for modern illumination sources including CFL (Compact Fluorescent), CCFL (Cold Cathode Fluorescent), LF (Linear Fluorescent) or MH (Metal Halide). Moreover, no account is made for the newest LED based poultry-specific illumination that is considerably different in spectral composition.

How light that birds see differs from source to source

The graphs at the right show the distribution of wavelengths from natural daylight and three artificial sources traditionally used in poultry houses. Considering how different these wavelength distributions are, and knowing that poultry are more sensitive to some wavelengths than others, it is easy to see why light from different sources looks so different to poultry – even when they look the same to us.

Why don't we see the differences? As shown earlier, we have narrower spectral sensitivity and we are far less sensitive to certain wavelengths. For example, we perceive standard incandescent bulbs as having a warm, yellowish light because we are not as sensitive to the red portion of the spectrum while birds will perceive it as a very reddish light. Typical light meters will not state correct light intensities for different artificial light sources because conventional measurements are based on human spectral sensitivity and calibrated to account for human eye photopic spectral response. These measure light in lux, the amount of total luminance of a surface where one lux is equal to one lumen per square meter. To differentiate, researchers and universities are commonly expressing illuminance for poultry in so called c-Lux (klux) or c-Lumen (luminous flux) which is adjusted to spectral response of domestic fowl instead of humans.

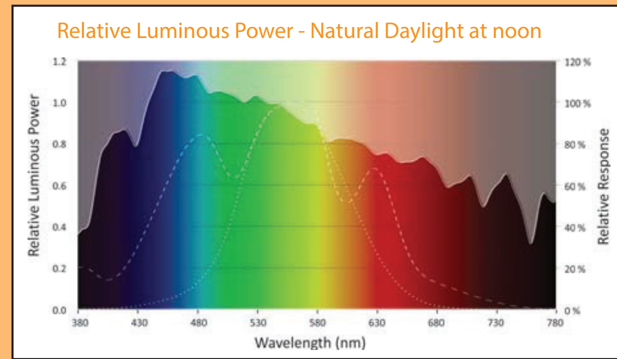
Comparison of Relative Intensity

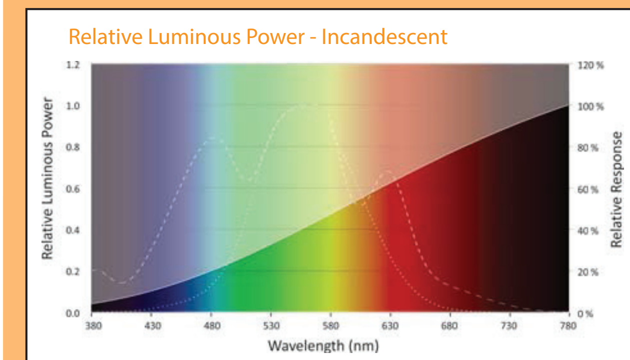
	Incandescent	CFL 6430°K
Turkey	1.24	1.16
Chicken	1.43	1.37
Duck	1.38	1.28
Human	1.0	1.0

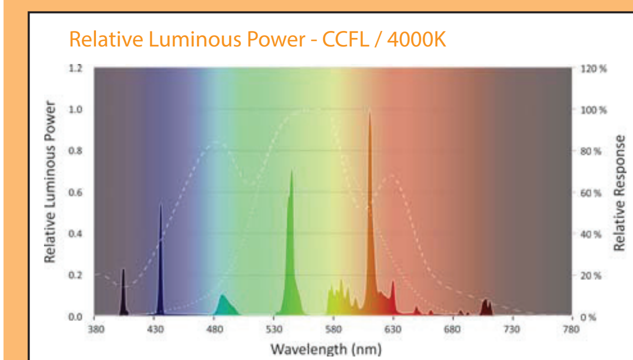
The chart above illustrates the relative intensity difference between an incandescent bulb and a CFL by showing the multiple factors between the three types of domestic fowl and humans.

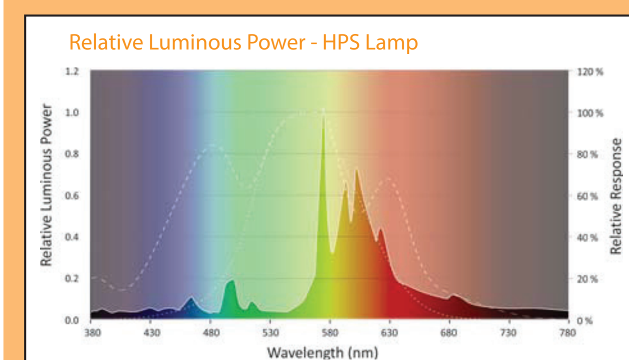
Source: Saunders J.E., Jarvis J.R., Wathes C.M. 2008. Calculating luminous flux and lighting levels for domesticated mammals and birds

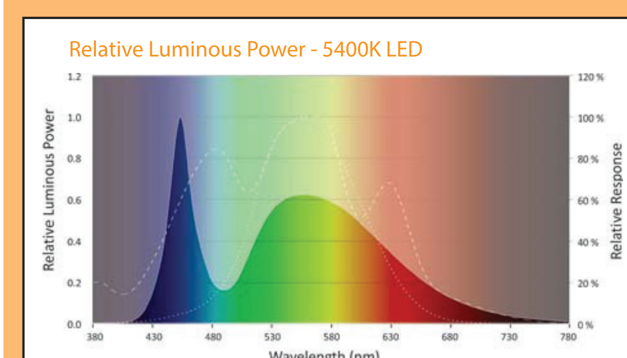
Traditional Lighting Sources





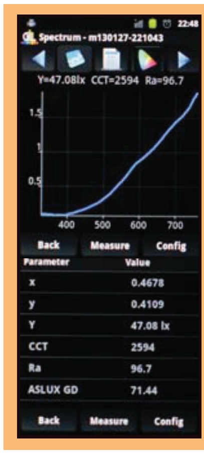






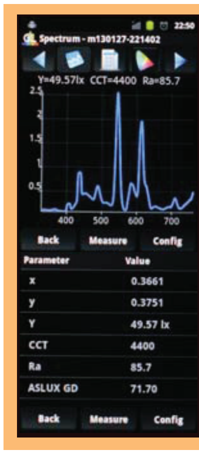
- - - - - Domestic Fowl Spectral Response
.... Human Eye Spectral Response

Differences Between Illuminance (Lux) and Animal Specific Irradiance (cLux)



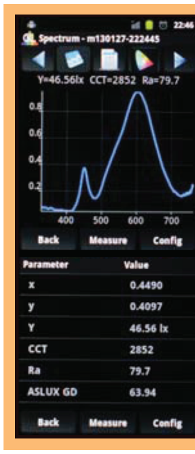
INCANDESCENT LAMP

Lux	47.8
cLux	71.4
Diff	49%



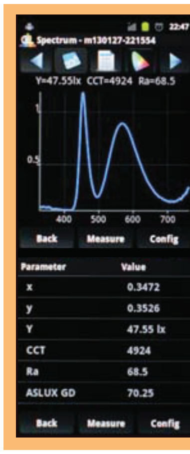
CFL DIMMABLE LAMP

Lux	49.6
cLux	71.7
Diff	44%



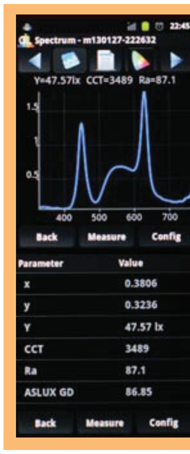
RESIDENTIAL LED LAMP

Lux	46.6
cLux	63.9
Diff	37%



GENERIC COOLWHITE LED

Lux	47.5
cLux	70.3
Diff	48%



AGRISHIFT LED LAMP LAYER SPECIFIC

Lux	47.5
cLux	87.1
Diff	83%

The importance of light color

Light source selection plays a very important role for poultry growers. As far back as 1987, the Wall Street Journal reported that chickens raised under full-spectrum lighting lived twice as long, laid more eggs, and were less aggressive than chickens raised under fluorescent lighting. They were more effective in metabolizing cholesterol and produced eggs 25% lower in cholesterol. Eggs were also larger and had stronger shells. What they may not have recognized then is the vast difference in color between the two sources.

Since that time, researchers have continued to study the effects of color – but not without controversy. Often the conclusions of their work is inconsistent or even contradictory. The main reason is the differences in the methodology. Each study involves an exponential number of variables. These include bird breed, barn differences (size, reflectivity, ceiling height, noise), climate and environment, seasonality, day periods of natural light, human interaction, light schedule, light source, intensity, color, light uniformity, health of flock, type and quality of electrical controls, and many other factors not easily documented or even recognized.

The entire scientific community agrees on basic physiological effects of light. (a) Light facilitates sight which is a necessity for food search; (b) Light entrains the circadian cycle; (c) Light initiates and regulates the release of multiple hormones which are essential in metabolic regulation, reproduction and bone formation.

The fact is that birds, poultry included, can perceive light in different, non-pictorial ways. This makes selection of the light source even more important. There are three key photosensitive areas: **(1) Retina** – In the retina, photons are absorbed in by photo-pigments rhodopsin (rods), iodopsin (cones) and recently discovered (1998) melanopsin. **(2) Pineal Gland** - Photon absorption is achieved by functional photoreceptors located in the pineal gland on the top of the brain. **(3) Hypothalamus** - Recently discovered photon absorption by deep encephalic photoreceptors. For retinal reception, light enters the retina directly; however, in the hypothalamus and the pineal gland, light must first penetrate the avian skull. The avian skull, skin, and brain tissue create a natural light filter. Due to the presence of blood (hemoglobin) in these tissues, red light penetrates the skull with the highest transmission efficiencies while blue green light is blocked almost completely.

With this in mind, we offer summations of what we believe to be reasonably well-documented findings. Even so, it is very important for poultry producers to learn as much as they can about light sources and light color, intensity, and schedules. We also encourage them to keep accurate records to assist in ongoing learning.

RED SPECTRUM One of the main functions of red light is Melatonin regulation and stimulation of reproductive activity. Red spectrum of the light is the only spectrum which entrains hypothalamic and pineal oscillators. The rhythm of melatonin synthesis is driven both by an extrapineal and an intrapineal oscillator entrained by light and dark information, which is perceived directly and indirectly by the pineal gland. Melatonin enhances the immune response and counteracts immunodeficiency states resulting from acute stress, viral diseases, aging, or drug treatment.

The hypothalamus is the reproductive controller of the hen. Contrary to what is believed, recognition of day length does not involve the eyes. The light response involves the stimulation of hypothalamic photosensitive cells by receiving light energy at photostimulation. That means that light intensity and spectrum must be adequate to have the light energy penetrate the feathers, the skin, the skull and the brain tissue. Light stimulation of the hypothalamus results in the secretion of Gonadotropin Releasing Hormone (GnRH). When activated by GnRH, the anterior pituitary secretes two gonadotropin hormones, Follicle-Stimulating Hormone (FSH) and Luteinizing Hormone (LH). FSH acts on sperm-producing structures in the testes, while LH acts on the interstitial cells of the testes causing them to secrete the steroid hormone testosterone. LH is essential for sexual maturation and for daily egg production to occur and is an integral component of the day-to-day events of ovulation.

There is a widely held belief now supported by research that red light increases the growth rate of chickens and turkeys when it's provided at the beginning of the rearing period. This is due to the fact that red light stimulates locomotion activity and the ability of adolecsent birds to more easily find and consume food. The increase in activity helps minimize leg disorders in the late rearing period.

There is also evidence indicating that actual feed consumption per egg laid is reduced under red lighting, particularly with wavelength above 640nm resulting in no difference in egg size, shell weight and thickness, or yolk and albumen weights. This suggests that light with a peak around 640nm, with the intensity reduced to the minimum required for egg laying, can reduce feed intake and reduce energy costs.

Other research indicates very narrow wavelength red light may help in manipulating the size of eggs, if the operation intends to provide smaller eggs.

BLUE AND GREEN SPECTRUM Consistently, research concludes monochromatic LED source lighting increases growth in broilers reared under green monochromatic light during the early stage by enhancing proliferation of skeletal muscle satellite cells.

Blue light has also been shown to be helpful in the growth and sexual development of poultry at a later age by elevation of plasma androgens.

Combined green and blue light promotes myofiber growth due to more effective stimulation of testosterone secretion. There is industry wide consensus that monochromatic blue light has a calming effect on animals which is particularly useful during semen collection from male turkeys.

Other studies show exposure to blue light causes a decrease in blood pressure and positively effects blood glucose levels and triglyceride levels.

One of the most evident drawbacks of incandescent and high pressure sodium lamps is a lack of blue spectrum essential for stimulating melanopsin, a photopigment found in specialized photosensitive ganglion cells of the retina that are involved in the regulation of circadian rhythms. With incandescent light, overall intensities must be extremely high to achieve blue levels sufficient to reset circadian cycles.

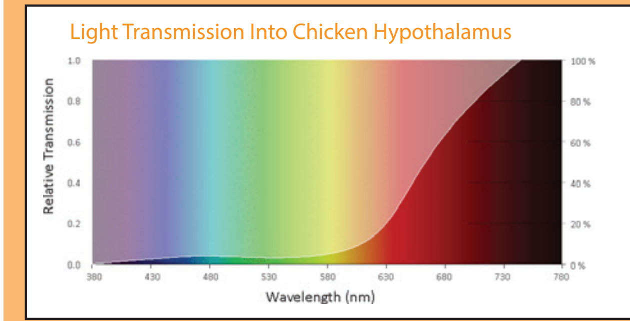
SUNSET AND SUNRISE It is proposed that the circadian pacemaker consists of two component oscillators. One is entrained to dusk and controls the onset of melatonin secretion. The second is entrained to dawn and controls the melatonin amplitude. The natural daylight spectrum during sunsets and sunrises is different from natural light at noon. There are also significant seasonal variances in the spectral composition of sunset and sunrise light. It is proposed that birds react not only to seasonal changes in daylength, but also seasonal changes in the light spectrum. These facts add to the importance of considering spectrum in the addition of sunrise/sunset controls in artificial lighting choices. The second picture on your right illustrates the typical spectrum of a summer sunset.

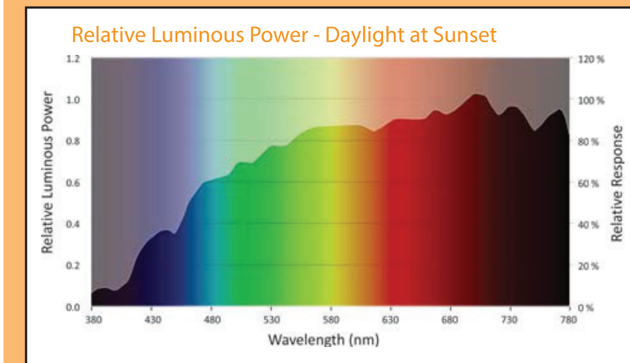
Poultry Specific Lighting

We've seen that color affects perceived light intensity in domestic fowl and that different light sources have different spectral distribution, some of which are more sensitive to poultry. Knowing this helps us understand that if we can dim the light in these sensitive wavelengths we can save electricity while still providing adequate light for birds.

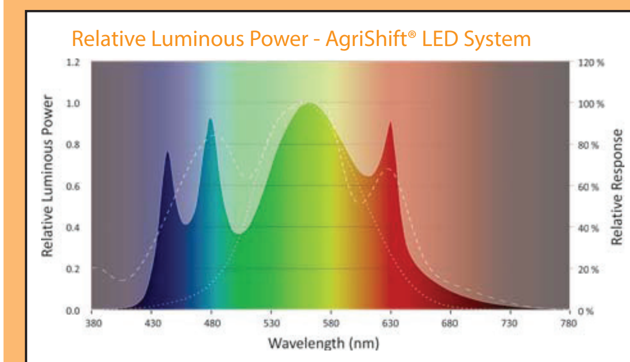
Using the distinct advantages of LEDs as a lighting source, ONCE has tailored the designs of the patented AgriShift® LED Poultry Lighting Systems to follow the spectral sensitivity curves of domestic fowl by using advanced, patented processes. In addition, we've incorporated advanced proprietary AC LED conditioning technology into the circuitry to enable smooth, selective LED dimming using standard commercial dimmers. This allows LEDs of different colors within the same lamp to be dimmed independently.

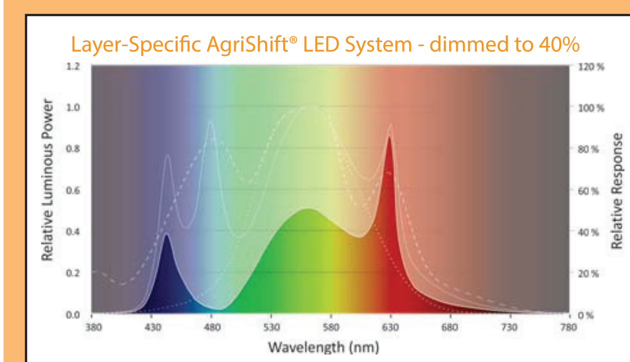
The graphs at right illustrate the potential of LED lighting for domestic fowl in general and the unique advantages from the poultry-specific lighting provided by AgriShift LED poultry lights. The first shows how the luminous power from an Agrishift system (at full intensity) mimics the spectrum response of poultry. Note the difference compared to traditional lighting sources shown on previous graphs. The second shows how the Layer-Specific AgriShift (dimmed to 40%) maintains the red wavelength at the point of peak poultry eye sensitivity, which is particularly important for layers and breeders. The third shows how the Broiler-Specific AgriShift light dimmed to 40% maintains the blue wavelength at the point of peak poultry eye sensitivity, which is particularly important for broilers and turkeys.

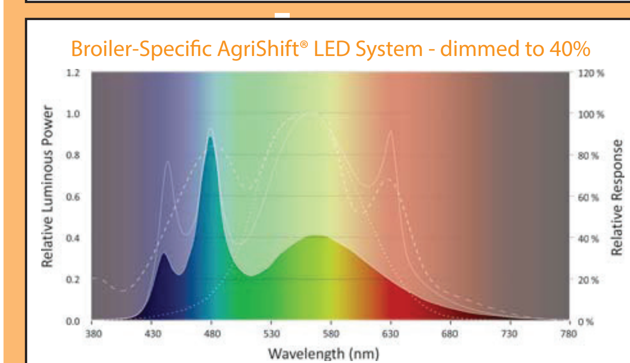




Poultry Specific AgriShift Lighting







- - - - - Domestic Fowl Spectral Response
. . . . . Human Eye Spectral Response
——— Agrishift at 100%

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This document is intended to be an educational introduction into factors that may affect poultry, including, but not limited to lighting sources, light schedule management, light color, and light intensities. It is not conclusive evidence from primary research conducted by Once Innovations, Inc. or any other single source. It summarizes, with good intent, how lighting factors may affect poultry or the lighting costs associated with poultry operations. Existing research and studies provided much of the source material for developing this introduction, however, it is important to note that results from studies seemingly evaluating the same variable(s) can, and often do, provide different, or even contradictory results. This variance can be attributed to many factors, both known and unknown, but include the fact that no two research methodologies are identical and in some cases are vastly different. These can include, but are not limited to, bird types, coop differences (size, reflectivity, ceiling height, noise, etc.), climate and environment, day periods of natural light, seasonality, human interaction, lighting schedule, intensity, color, source, quality of source, optics packages, health and welfare of flock, type and quality of electrical controls including dimmers, and the existence of other factors not easily recognized or documented. For these reasons, specific studies used as references have not been directly identified or attributed to what could be inaccurately assumed to be conclusions from any single study. Once Innovations, Inc. makes no guarantees or accepts any liability with regard to flock performance using the AgriShift Poultry Light or any of the information contained in this document. The poultry operation takes full responsibility for decisions regarding the type and usage of lighting and the results stemming from those decisions.

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