Outline

- Poultry biology
- Understanding light
- Measuring light
- Impact of painting lights red
- Lens dispersion and dimming
- LED light overview
- Choosing the right light
Human wavelength recognition

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Fowl wavelength recognition
Lux versus clux

- The International Commission on Illumination (CIE) standard for measuring light intensity is set at the peak human response.
- Humans only have one photopic spectral peak that is calculated between 550 – 560 nm.
- Chickens have 3 photopic spectral peaks (around 480, 560, and 625 nm); therefore some additional calculations are required.
- Depending on the light source and peak spectrum, there can be a 50% or greater difference between the lux and clux.
Basic Physiological effects of light:

1. Facilitate sight →
   - Food search

2. Stimulate Internal Cycles →
   - Circadian- day length changes

3. Initiate and regulate hormone release →
   - Metabolic regulation: fat & muscle deposition
   - Reproduction
   - Calcium, phosphorus, and bone formation
Poultry biology

Reception:

1. Retinal →
   - Cone photoreceptors
   - Visual perception
   - Dopamine & UV-A ↔ melatonin

2a. Pineal → “Soul gland”
   - Photoreceptors (>4 lux)
   - Circadian clock: serotonin and melatonin

2b. Hypothalamic → Sexual Maturity
   - Deep encephalic photoreceptor
   - Sexual hormones
Spectral transmission into the hypothalamus in birds
Spectral transmission into the hypothalamus in birds

<table>
<thead>
<tr>
<th>Wavelength (nm)</th>
<th>Quail</th>
<th>Sparrow</th>
<th>Pigeon</th>
<th>Ducks</th>
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</thead>
<tbody>
<tr>
<td>Violet (400-435)</td>
<td>0.013</td>
<td>0.018</td>
<td>0.275</td>
<td></td>
</tr>
<tr>
<td>Blue (435-500)</td>
<td>0.023</td>
<td>0.055</td>
<td>0.098</td>
<td>0.027</td>
</tr>
<tr>
<td>Green (500-565)</td>
<td>0.020</td>
<td>0.067</td>
<td>0.113</td>
<td>0.096</td>
</tr>
<tr>
<td>Yellow (565-600)</td>
<td>0.090</td>
<td>0.135</td>
<td>0.158</td>
<td>0.244</td>
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<tr>
<td>Orange (600-630)</td>
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<td>0.271</td>
<td>0.280</td>
<td>0.410</td>
</tr>
<tr>
<td>Red (650)</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
<td>1.000</td>
</tr>
<tr>
<td>Red (700)</td>
<td></td>
<td>2.927</td>
<td>11.681</td>
<td></td>
</tr>
</tbody>
</table>
Poultry physiology

- Wavelength differences

- Ultraviolet A-B light
  - Vitamin D conversion, calcium and phosphorus metabolism, bone formation, immune system, blood pressure and circulation, muscle development

- Visual light
  - Birds have 4 types of single-cone photoreceptors and tetra-chromatic color vision
  - A 5th single-cone is luminance based for motion detection

- Infrared light
  - Perceived as heat
Understanding light
Basic Concepts

Light

- Portion of the Electromagnetic Spectrum
- Radiation

- Ultra Violet (UV)
- Visible
- Infra red (IR)

Light Environment:

- Duration → e.i., Photoperiod, Day length
- Luminance → e.i., Intensity
- Wavelength → e.i., Color
Electromagnetic spectrum

Penetrates Earth’s Atmosphere?

Radiation Type Wavelength (m)

- Radio: $10^3$
- Microwave: $10^{-2}$
- Infrared: $10^{-5}$
- Visible: $0.5 \times 10^{-6}$
- Ultraviolet: $10^{-8}$
- X-ray: $10^{-10}$
- Gamma ray: $10^{-12}$

Approximate Scale of Wavelength

- Buildings
- Humans
- Butterflies
- Needle Point Protozoans
- Molecules
- Atoms
- Atomic Nuclei

Temperature of objects at which this radiation is the most intense wavelength emitted

- $1 \text{ K} = -272 \degree C$
- $100 \text{ K} = -173 \degree C$
- $10,000 \text{ K} = 9,727 \degree C$
- $10,000,000 \text{ K} = \sim 10,000,000 \degree C$

Frequency (Hz)

- $10^4$
- $10^8$
- $10^{12}$
- $10^{15}$
- $10^{16}$
- $10^{18}$
- $10^{20}$

Courtesy of Wikimedia Commons
Chromaticity

- Chromaticity is a method to measure the relative warmness or coolness of light
- Expressed in degrees of Kelvin
  - Was originally developed for incandescent lights
  - $>4000K$ - cool
  - $3500 – 3600$ K – neutral and balanced
  - $<3000K$ - warm
Luminous Flux

Luminous flux – the total emitted visible light from a bulb, measured in lumens

Source Gigahertz-Optik LED Tester Data Sheet
Luminous intensity (directional flux) – quantifies the luminous flux emitted by a light source in a certain direction, measured in candelas or candles

\[ I_e = \frac{d \Phi_e}{d \Omega_1} \]
Illuminance power – the luminous flux per area illuminated by the light, measured in lux or foot candles (fc). The calculation is 1 lux = 1 lumen/m² or 1 lux = 0.0929 fc (lumen/m²).
Light measurement

- Light meters are used to measure lux or foot candle
  - 1 fc = 10.76 lux or 1 lux = 0.0929 fc
  - Equals conversion between 1 ft\(^2\) and 1 m\(^2\)

- All light meters are not created equal
  - Traditional light meters only take into account peak human vision at around 555 nm
  - Animal specific light meters can calculate the full spectrum vision
  - Good light meters are scientific instruments and are priced accordingly!
Measuring LED light intensity

Traditional light meters cannot be used to measure LED lights accurately in a poultry house.

Most light meters are calibrated for visible light at a "white" color temperature, usually ~2800K and most closely associated with ~550-560nm wavelengths.

Traditional light meters do give a rough indication of light intensity.

Traditional light meters are still useful for assessing the difference in light intensity between different areas.
Measuring LED’s

- **Ideal LED light meters can be poultry or LED specific**

- **Poultry spectrometers**
  - Once and Hato
  - Provide lux and clux reading
  - Also gives CCT, CRT, λp

- **LED spectrometers**
  - Used by professional photographers
  - Gives readings for CCT, CRI, Lux, λp (peak wavelength)
  - Does not give clux, but this can be roughly assessed based on observing the spectrum
Spectrometer reading

CCT: 2960 K
CRI: 82
LUX: 578
λp: 606 nm

I-Time: 588 ms

CIE1931:
X: 0.4464
Y: 0.4184

CIE1976:
u': 0.2505
v': 0.5283
Spectra of different light sources
Sunlight at noon
Sunlight at dawn
Warm LED (2700K)
ONCE Innovations LED
Colored curtains

Graphs showing light spectra and measurements:
- **λp**: 458 nm
  - CCT: 3049 K
  - CRI: 78
  - LUX: 3877
- **λp**: 748 nm
  - CCT: 3049 K
  - CRI: 78
  - LUX: 3877

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Painting bulbs red
Painting bulbs red

Many producers paint bulbs red as a tool to dim light and/or prevent pecking.

What is the actual effect of painting a bulb red?
Dimming effect of red paint

- LED2 5000K painted: 28 Lux
- LED2 5000K: 95 Lux
- LED2 2700K painted: 38 Lux
- LED2 2700K: 92 Lux
- LED1 5000K painted: 25 Lux
- LED1 5000K: 123 Lux
- LED1 2700K painted: 26 Lux
- LED1 2700K: 90 Lux
- INC1 2750K painted: 19 Lux
- INC1 2750K: 93 Lux
- CFL1 5000K painted: 12 Lux
- CFL1 5000K: 108 Lux
- CFL1 2700K painted: 28 Lux
- CFL1 2700K: 127 Lux
# Dimming effect of red paint

<table>
<thead>
<tr>
<th>Light Type</th>
<th>Lux</th>
<th>Painted red</th>
<th>% dim</th>
</tr>
</thead>
<tbody>
<tr>
<td>CFL1 2700K</td>
<td>127</td>
<td>28</td>
<td>78%</td>
</tr>
<tr>
<td>CFL1 5000K</td>
<td>108</td>
<td>12</td>
<td>89%</td>
</tr>
<tr>
<td>INC1 2750K</td>
<td>93</td>
<td>19</td>
<td>80%</td>
</tr>
<tr>
<td>LED1 2700K</td>
<td>90</td>
<td>26</td>
<td>71%</td>
</tr>
<tr>
<td>LED1 5000K</td>
<td>123</td>
<td>25</td>
<td>80%</td>
</tr>
<tr>
<td>LED2 2700K</td>
<td>92</td>
<td>38</td>
<td>59%</td>
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<tr>
<td>LED2 5000K</td>
<td>95</td>
<td>28</td>
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<td>CFL1 5000K</td>
<td>108</td>
<td>12</td>
<td>89%</td>
</tr>
</tbody>
</table>
Cool LED 5000K

- Full light
- Red light
Painting bulbs red

- **Red paint creates significant dimming**
  - 58 – 88% in this experiment
  - Does not provide uniform dimming

- **Red paint blocks almost all blue, green, and yellow spectrum**
  - The level of spectrum cutoff depends on the paint used
  - This paint was around 600 – 620 nm

- **Red paint does not create any new red spectrum**
  - Only utilizes the red spectrum already available but at a lower intensity

- **Installing dimmable lights can accomplish a very similar effect to painting with no extra labor or new bulb cost**
LED dimming and lens dispersion
Dimming LED lights

- Dimmers need to be compatible with the specific LED lights installed
- Incompatible dimmers may cause LED lights to flicker, overheat, or burn out more quickly
- Incandescent and LED dimmers both operate similarly; however, LED dimmers must have greater control of wattage output
- The main reason for the difference in dimmer compatibility is the filament in an incandescent light source is a simple resistor
**Dimming LED lights**

- LED light do not have a resistive filament, and by design are complex loads.

- A good LED dimmer will have resistance built into the dimmer to control the output of electricity to ensure consistent performance when dimmed.

- LED lights maintain efficiency when dimmed, and may also increase the bulb life.
Lens dispersion

- Understand the difference in bulb directionality
  - 180° bulb very different than an 30° bulb

- Lights with high level of light dispersion
  - CFL, incandescent

- Directionality can be useful or detrimental depending on the intended purpose

- Directional bulbs can save energy by focusing light where needed

- Bulb directionality matters in both cage and floor houses
  - Floor – spotlighting, floor eggs
  - Cage – cages that are too dark or too bright
Light dispersion
Light dispersion in cages
Light dispersion in cages

Illuminance power (lux/clux)

Distance between lights (feet)

lux top
lux bottom
LED Benefits

- Full spectrum light
- Most efficient light bulb measured in lumens per watt
- Low infrared radiation (heat)
  - Non-glass materials allow for manufacture from waterproof and shatterproof materials
- Spectrum can be shifted
- Easier to dim than CFL bulbs
- Typically manufactured from non-toxic materials
- Long lifespan – up to 10 years @ 16 hrs (50,000 – 60,000 hours)
- Rapidly reaches peak light intensity after being turned on
- Ideal for areas where lights are turned on and off frequently
- Able to be used in cold weather
LED Shortcomings

- Expensive – current poultry specific LED lights may cost $20 - $35 per bulb.
- General LED lights run $2 - $15
- Correct dimmer must be used otherwise the light may flicker and burn out more quickly
- Not all LED’s have a good lens to diffuse the light in all directions
- The lack of sufficient light diffusion may cause dramatic changes in light intensity at the feeder if lights are placed too far apart
- 4 m centers may be too far apart for most LED lights, 2 m or 3 m centers are more ideal
Types of LED bulbs

**General**
- Available at online and in hardware stores
- Becoming less expensive
- Not created for usage in agriculture environments
- Some may not be warrantied for agriculture use
- Typical warm and cool spectra

**Poultry specific**
- Good technical support
- Good track record of installation
- Designed to meet electric codes in barns
- Great warranties for light performance
- Most expensive
## Return on Investment

<table>
<thead>
<tr>
<th>Light type</th>
<th># Lights</th>
<th>Watt/ Bulb</th>
<th>Hour/ day use</th>
<th>Energy cost kW/hr ($)</th>
<th>Cost per bulb ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED</td>
<td>165</td>
<td>8</td>
<td>16</td>
<td>€ 0.15</td>
<td>€ 7.00</td>
</tr>
<tr>
<td>CFL</td>
<td>165</td>
<td>13</td>
<td>16</td>
<td>€ 0.15</td>
<td>€ 1.50</td>
</tr>
<tr>
<td>Incandescent</td>
<td>165</td>
<td>60</td>
<td>16</td>
<td>€ 0.15</td>
<td>€ 1.00</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Operation plus bulb cost ROI

<table>
<thead>
<tr>
<th>Bulb</th>
<th>Install bulb cost</th>
<th>Yearly energy cost</th>
<th>ROI for LED*</th>
</tr>
</thead>
<tbody>
<tr>
<td>LED</td>
<td>€ 1,155.00</td>
<td>€ 1,156.32</td>
<td>16 months</td>
</tr>
<tr>
<td>CFL</td>
<td>€ 247.50</td>
<td>€ 1,879.02</td>
<td></td>
</tr>
<tr>
<td>Incandescent</td>
<td>€ 165.00</td>
<td>€ 8,672.40</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>€ -</td>
<td>€ -</td>
<td></td>
</tr>
</tbody>
</table>

### ROI for LED*

- **LED**: 16 months
- **CFL**: 5 months
- **Incandescent**: 51 months
- **Other**: -

---

<table>
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<tr>
<th>Light type</th>
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<tbody>
<tr>
<td>LED</td>
<td>165</td>
<td>8</td>
<td>16</td>
<td>€ 0.15</td>
<td>€ 3.00</td>
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<td>CFL</td>
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<td>16</td>
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<td>16</td>
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<td>Other</td>
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### Operation plus bulb cost ROI

<table>
<thead>
<tr>
<th>Bulb</th>
<th>Install bulb cost</th>
<th>Yearly energy cost</th>
<th>ROI for LED*</th>
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</thead>
<tbody>
<tr>
<td>LED</td>
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<td>5 months</td>
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<td>CFL</td>
<td>€ 247.50</td>
<td>€ 1,879.02</td>
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<tr>
<td>Incandescent</td>
<td>€ 165.00</td>
<td>€ 8,672.40</td>
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</tr>
<tr>
<td>Other</td>
<td>€ -</td>
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### ROI for LED*

- **LED**: 5 months
- **CFL**: -
- **Incandescent**: -
- **Other**: -

---

<table>
<thead>
<tr>
<th>Light type</th>
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<table>
<thead>
<tr>
<th>Bulb</th>
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</thead>
<tbody>
<tr>
<td>LED</td>
<td>€ 3,300.00</td>
<td>€ 1,156.32</td>
<td>51 months</td>
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<tr>
<td>CFL</td>
<td>€ 247.50</td>
<td>€ 1,879.02</td>
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<td>€ 165.00</td>
<td>€ 8,672.40</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>€ -</td>
<td>€ -</td>
<td></td>
</tr>
</tbody>
</table>

### ROI for LED*

- **LED**: 51 months
- **CFL**: -
- **Incandescent**: -
- **Other**: -

---
What bulb should I choose?

Great question!

Depends on available capital

Building a new farm, renovating, or only retrofitting

What kind of housing system

- Barn, aviary, colony, enrichable cage, traditional cage

Understand that LED light technology is rapidly improving

- Quality will improve and cost will decrease in the coming years
Regardless of bulb…

- Be aware of the specifics of the bulb chosen
  - Lumen output, spectrum, test the bulb in the house first if possible
- Invest in a proper dimmer
  - LED’s are computer chips and need surge protection
- Think long term
- For laying hens, use a 2700K - 3500K bulb to help ensure red spectrum availability
- For pullets, either warm or cool bulbs can be used
- Space the bulbs appropriately to minimize shadows or excessively bright areas