Vision in agricultural animals – What do they see and how do they respond?
Poultry, Swine, and Aquaculture

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Visual Retinal Photoreception (through the eyes)

Rod = Detects Low Intensity Light
Cone = Detects Color under higher intensities

Humans are Trichromatic
Birds are Tetrachromatic

Source: “Avian Cone Photoreceptors Tile the Retina as Five Independent, Self-Organizing Mosaics” Yoseph A. Kram, Stephanie Mantey, Joseph C. Corbo, 2010
Typical Photopic Spectral Sensitivity

Humans

Domestic Fowl

- 12 times more sensitive to blue spectrum
- 4 times more sensitive to red spectrum
- Ability to see UV A light

Data source: “Spectral sensitivity of the domestic fowl (Gallus g. domesticus)” N. B. PRESCOTT AND C. M. (1999)
Poultry perceive light through the eye as well as through extra-retinal neural pathways

• **1. Visual, Retinal Reception** – Photon absorption by photo-pigments rhodopsin (rods), iodopsin (cones) and recently discovered (1998) melanopsin

• **2a. Non-visual / Pineal Reception** - Photon absorption by functional photoreceptors located in pineal gland on the top of the brain

• **2b. Non-visual / Hypothalamic Reception** - Photon absorption by deep brain encephalic photoreceptors
Deep red light penetrates best though the skull of birds

Avian skull, skin and brain tissue create natural light filter. Due to presence of blood in the tissue, red light penetrates skull with highest transmission efficiencies.

The color landscape is more complex to poultry

Human Spectral Sensitivity

Poultry Spectral Sensitivity
Red color

- Increases the growth rate of chickens and turkeys at the beginning of the rearing period
- Increases locomotion that helps minimize leg disorders in the late rearing period
- Stimulates secretion of Gonadotropin Releasing Hormone (GnRH), essential for sexual maturation
- Stimulates day-to-day events of ovulation / egg production
- Reduces actual feed consumption per egg laid with no differences in egg size, shell weight, shell thickness, or yolk and albumen weights
- Stimulates / Improves Melatonin production
Green, Blue color

- *Green light significantly enhances growth rate at an early age* by enhancing proliferation of skeletal muscle satellite cells

- *Blue light enhance growth at a later age by elevation in plasma androgens*

- *Blue light spectrum region between 446–477 nm is identified as the most potent wavelength region providing circadian input for regulating melatonin secretion*

- *Green and Blue light promote myofiber growth due to more effective stimulation of testosterone secretion*

- *Narrow band blue light reduces locomotion*
UVA vision plays an important role in social and feeding behaviors


Pullets prefer to dwell under UV-A

Research conducted at Iowa State University by Kai Liu and Hongwei Xin:

*Under non-choice experiment: No apparent differences observed in weight gain, total feed consumed, FCR, activity levels, or eye conditions.
Broiler welfare is improved under UV-A

Research conducted at Texas A&M University by Gregory Archer (unpublished) showed that supplementing with UV-A:

- Reduced stress biomarkers:
  - 3X less corticosterone
  - 2X lower H:L ratio
  - Lower body asymmetry

- Reduced fear responses
  - Lower tonic immobility times
  - Fewer inversion wing flaps
Dynamic lighting

R/G/B/W/UV
Spectrum Controllable lighting fixture

Spectrum and Intensity Lighting Recipe

Wireless Gateway

LoRa

SPECTRUM Rx
SENSOR DATA

Cloud Computing / Machine Learning / Algorithm Creation

Spectrum Recipe for Real Time Control Of

- Average Daily Gains
- FCR
- Daily Activity / Locomotion
- Sleeping Cycle
- Aggressivity / Pecking Behaviors
- Activity (BTU) in extremely hot days
- Myopathy
- Movement to / from Preferential areas
- Sexual Maturation and oviposition timing
- Piling behavior
- Disease Alerts

Wireless Barn Data Collection Sensors
Circadian Lighting during egg incubation improves hatchability and chick quality


Archer, G., Mench, J., 2014a. Natural incubation patterns and the effects of exposing eggs to light at various times during incubation on post-hatch fear and stress responses in broiler (meat) chickens. APPLIED ANIMAL BEHAVIOUR SCIENCE 152, 44–51.


Green lighting during incubation improves muscle development


Human vs Swine vision

Human

Swine
Shifting to red color as light dims allows workers to observe pigs without disturbing animal’s circadian rhythm
Lighting Schedule - Farrowing Room without feeding stimulus

- Feeding: Ad libitum / Restricted
- Day Length: 16 Hours
- Digestion time: Cont./ 8 hours
- Sunset: 60 minutes
- Sunrise: 60 minutes
Lighting can influence productivity enhancements

- Reduction in animal stress levels
- Modification of feeding behavior
- Enhancing fertility and stimulating mating cycle
- Accelerated growth / Average daily gains
- Improved feed conversion
- Heavier average piglet wean weight
- Lower prewean mortality
Animal Welfare

• Lighting systems and programs improve animal welfare by reducing stress and violent behavior among animals under care
• Reduced mortality and damage to the animal prior to harvest
• Enhanced immune system reduces need for antibiotic treatments
• Calm animals are happy and healthy resulting in accelerated growth and well being
The working of light: Fish Differ from People

Eye sensitivity

Eyes: 430 - 770nm
Pineal: no sensitivity

Pineal sensitivity

Eyes: 420 – 650nm
Pineal: ~ 400 – 700nm
Benefits of Marine Based LED Lighting

- **Optimal fish light spectrum**
  - Visual: better visibility of feed
  - Pineal gland: maturation prevention
  - Increase growth, better feed conversion ratio

- **Optimal light distribution**
  - Homogenous light distribution in the cage
  - Downward facing light to keep fish below sea lice zone
  - Makes sure light is optimal at cooler depths

- **Optimal light control**
  - Easy-to-use operator interface
  - Low dimming to avoid stress
  - Easy to adjust light recipes
  - Energy saving by daylight harvesting
  - Dimming to control fish depth
Lighting As Control Tool For Salmon Development

- Increase growth
- Reduce FCR
- Reduce stress
- Improve smoltification
- Reduce mortality after sea transfer

- Shorten spawning time
- Improve egg quality

- Increase growth
- Reduce FCR
- Reduce mortality
- Improve welfare
- Reduce sea lice
- Reduce sexual maturation

- Advance smoltification of juvenile salmon during freshwater stage

- Increase growth
- Reduce FCR
- Reduce stress
- Improve smoltification
- Reduce mortality after sea transfer
# LED Lighting Production Results

<table>
<thead>
<tr>
<th>Company</th>
<th>Increased growth</th>
<th>Maturation reduction</th>
<th>b-FCR reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lerøy</td>
<td>15%</td>
<td>-2,5%</td>
<td>-7,9%</td>
</tr>
<tr>
<td>Marine Harvest</td>
<td>10%</td>
<td>-3,1%</td>
<td>-14,2%</td>
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<td>Company A**</td>
<td>15,7%</td>
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<tr>
<td>Company B*</td>
<td>5%</td>
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<td>NA</td>
</tr>
<tr>
<td>Company C</td>
<td>11%</td>
<td>-6%</td>
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<tr>
<td>Company D</td>
<td>16%</td>
<td>-22%</td>
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<tr>
<td>Company E</td>
<td>12.3% 5.9%</td>
<td>-0.7% +0.5%</td>
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<tr>
<td>Company F</td>
<td>3,6% 14,2%</td>
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<td>NA</td>
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<tr>
<td>Company G**</td>
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<td>-11,8%</td>
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<tr>
<td>Company H</td>
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<tr>
<td>Company I***</td>
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<td>-12%</td>
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<tr>
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<td></td>
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<tr>
<td>Company K**/***</td>
<td>22% 8% 14%</td>
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<tr>
<td>Company L**</td>
<td>28%</td>
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<tr>
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<td></td>
</tr>
<tr>
<td>Company N</td>
<td>10,0%</td>
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</tr>
<tr>
<td><strong>Average</strong></td>
<td><strong>12,8%</strong></td>
<td><strong>-2,5%</strong></td>
<td><strong>-9,2%</strong></td>
</tr>
</tbody>
</table>

* Used high-energy feed

** all year round lighting regime

*** Other LED as control group
Submerged aquaculture lighting combats sea lice

Metal Halide & other LED luminaires

Species Specific LED luminaire

- fish tend to swim deeper
- fish swim below sea lice zone
- fish swim in cooler water
- you have no light pollution

Keeping the fish below the sea lice zone in summer has proven to reduce the number of treatments by >40% (average of 5 trials)

Norwegian customer quote:
“We reduced >50% of sea lice treatment by having the right light level during the summer”