Factors affecting embryo temperature and their effects on chick quality

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- 1996 MSc in Fisheries Biology & Aqua Culture
- 1997 Laboratory Salmonella & Campylobacter Piukon Poultry
- 1998 Center for Applied Poultry Research “Het Spelderholt”
- 2003 Researcher Poultry Production at Wageningen UR Livestock Research
- 2007 Researcher Healthy Chicks in Healthy Poultry Chains at WUR-LR
- 2008 PhD “embryo temperature during incubation: practise and theory”
- 2012 www.hatchability.com – a website to inspire hatchery workers

Recent projects:
- Reduction of antibiotics and ESBL in the Dutch Broiler Chain
- Optimising technical and financial results in all sectors in the broiler chain
- Food Security Project in Indonesia on broiler farming
- Pilot farms and hatchery development in India
Incubation for good chick quality

- Machine temperature ≠ embryo temperature
- Balance between heat loss and heat production (HP)
- Factors that affect heat loss
- Factors that affect HP
- Effects of uncontrolled embryo temperature

Machine temperature ≠ embryo temperature

![Graph showing heat production, heat loss by evaporation, embryo temperature, and machine temperature over time.](image-url)
Machine temperature ≠ embryo temperature

![Graph showing heat production and loss, embryo temperature, machine temperature over time.]

Development
Growth
Plateau phase
Internal pippling
External pippling

- Heat production
- Heat loss by evaporation
- Embryo temperature
- Machine temperature

Time (d)
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

Heat production of loss (mW)
0 50 100 150 200 250 300

Temperature (ºC)
37.0 37.5 38.0 38.5 39.0 39.5

Machine temperature ≠ embryo temperature

![Graph showing heat production and loss, embryo temperature, machine temperature over time.]

Development
Growth
Plateau phase
Internal pippling
External pippling

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37.0 37.5 38.0 38.5 39.0 39.5
Machine temperature ≠ embryo temperature

![Graph showing heat production, heat loss by evaporation, embryo temperature, and machine temperature over time.](image)

- **Heat production**
- **Heat loss by evaporation**
- **Embryo temperature**
- **Machine temperature**

**Legend:**
- Development
- Growth
- Plateau phase
- Internal pipping
- External pipping

**Axis:**
- Heat production of loss (mW)
- Temperature (ºC)

**Time (d):**
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

**Graph:**
- **Heat production**
- **Heat loss by evaporation**
- **Embryo temperature**
- **Machine temperature**

**Key:**
- Machine temperature ≠ embryo temperature
Machine temperature ≠ embryo temperature

- Air temperature
- Eggshell temperature
Machine temperature ≠ embryo temperature

\[ \text{ET} - \text{MT} (\degree\text{C}) \]

- \( v = 0.0 \text{ m/s} \)
- \( v = 0.1 \text{ m/s} \)
- \( v = 0.5 \text{ m/s} \)
- \( v = 2.0 \text{ m/s} \)

\[ \text{Time (d)} \]

0 2 4 6 8 10 12 14 16 18 20
Machine temperature ≠ embryo temperature

- MT = ET only at 1 point, when heat loss = heat production
- timing depends on air velocity across the eggs
- differences between incubators
- differences between positions in the incubator

**ET: balance between heat production and heat loss**

Embryo temperature (ºC)

<table>
<thead>
<tr>
<th>Temperature (ºC)</th>
<th>36</th>
<th>36.5</th>
<th>37</th>
<th>37.5</th>
<th>38</th>
<th>38.5</th>
<th>39</th>
<th>39.5</th>
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<td>- air velocity</td>
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<td></td>
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</tbody>
</table>

Heat production
- Time / development
- Physical factors
- Biological factors
- Environmental factors
1. Factors that affect heat loss

2 components that determine heat loss:

- Evaporation (latent HP)
  - relative humidity and air temperature
  - eggshell quality
- Heat transfer
  - temperature difference between egg and environment
  - heat capacity of air (relative humidity)
  - air velocity

![Graph showing heat loss by evaporation and relative humidity](image-url)
Heat loss: evaporation

- Weight loss: 10,000 eggs of 60 g loose 0.6% of initial weight per day
  - Eggs incubated at 37.5°C MT and 55% RH
  - Total weight loss: 150 ml water per hour
  - ET is decreased by 0.2°C
  - Uniform at all places in the incubator

Spray nozzles or humidifying discs:
- Local cooling effects
- 150 ml water per hour at 10% of the eggs: ET is decreased by 2.0°C!
Heat loss: heat transfer

Calculated for eggs incubated at the same MT
2. Factors that affect heat production

- Age of the embryo (time)
- Physical factors
  * storage conditions, egg turning
- Biological factors
  * egg size, breed, breed age
- Environmental factors
  * oxygen, carbon dioxide, humidity, temperature

![Diagram showing the relationship between oxygen, carbon dioxide, and heat production.]

Physical factors: egg storage

![Graph showing heat production over time with different storage conditions.]

Hague et al., 1996
Physical factors: egg turning

Pearson et al., 1996

Biological factors: egg size

Hoyt (1987)
Vleck et al. (1987)
Biological factors: egg size

Lourens et al., 2006
Biological factors: breed

Metabolic heat production (mW per egg)

<table>
<thead>
<tr>
<th>d</th>
<th>R308*</th>
<th>R508*</th>
<th>Layer*</th>
<th>Traditional**</th>
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<td>17</td>
<td>151</td>
<td>160</td>
<td>133</td>
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<td>20</td>
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<td>131</td>
<td>169</td>
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</table>

*Janke, Tzsehenkte and Boerjan (2004)
** Romijn and Lokhorst (1960)

Differences between lines, genetic background

- Not much “hard” information
  - Mainly focus on layers vs broilers

- But practical experience:
  - easy
    - Vedette, AA
    - Ross 308, hubbard classic, Hybro PN
    - Ross 508,
    - Ross 708, cobb 500, Hybro G+, Hubbard HY
    - Cobb 700, male lines
  - difficult
General trend:

- More meat yield ➔ higher heat production
- Better shell quality ➔ more sensitive for heat

If people change breed, look where they come from

- Ross to Cobb: possible problems
- R508 to R308: more easy
- Cobb 500 to Cobb 700: be aware
  - 0.5 to 1°F higher embryo temperature at same setting
  - 6-12 hours earlier hatch
  - More chick quality issues if temperature not adjusted

Biological factors: breed

- Broiler and layer hatching eggs incubated at the same constant MT
- Differences in egg size
- Eggshell temperature at d18 for layer eggs: 38.3°C
- Eggshell temperature for broiler eggs: 0.6 – 0.8°C higher
  - metabolic rate higher
  - HP and ET are linearly related
  - oxygen conductance in broiler eggs higher? (poor eggshell quality?)
  - Broiler embryos contain and utilize more energy?
  - Efficiency of energy utilization??
Experiment with broiler hatching eggs (Lourens et al., 2007):

- Eggs of similar size: 60 – 65g
- EST between d8 – d19: 37.8°C or 38.9°C
- O2: 17%, 21% or 25%

Climate Respiration Chamber (CRC)
Control Room
**Source of variation**

<table>
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<tr>
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<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
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<td>*</td>
<td>*</td>
<td>**</td>
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<td>*</td>
<td>**</td>
<td>**</td>
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<td>EST x O2</td>
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<td>-</td>
<td>-</td>
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</table>

**Heat production (mW egg⁻¹)**

![Graph showing heat production over time with different conditions and variations.](image)

**CL** | **BW** | **YFB** | **RY** | **HW** | **LW** | **HT**
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<tr>
<td>(cm)</td>
<td>(g)</td>
<td>(g)</td>
<td>(g)</td>
<td>(g)</td>
<td>(g)</td>
<td>(d)</td>
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</table>

**EST**

- **37.8°C**
  - 19.7
  - 41.5<sup>a</sup>
  - 37.4<sup>a</sup>
  - 4.0
  - 0.40<sup>a</sup>
  - 1.65<sup>a</sup>
  - 20.5<sup>a</sup>

- **38.9°C**
  - 19.8
  - 39.8<sup>b</sup>
  - 35.8<sup>b</sup>
  - 4.0
  - 0.33<sup>b</sup>
  - 1.53<sup>b</sup>
  - 19.8<sup>b</sup>
<table>
<thead>
<tr>
<th></th>
<th>CL (cm)</th>
<th>BW (g)</th>
<th>YFB (g)</th>
<th>RY (g)</th>
<th>HW (g)</th>
<th>LW (g)</th>
<th>HT (d)</th>
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<td>37.8°C</td>
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<td>41.5a</td>
<td>37.4a</td>
<td>4.0</td>
<td>0.40a</td>
<td>1.65a</td>
<td>20.5a</td>
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<tr>
<td>38.9°C</td>
<td>19.8</td>
<td>39.8b</td>
<td>35.8b</td>
<td>4.0</td>
<td>0.33b</td>
<td>1.53b</td>
<td>19.8b</td>
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<td>O2</td>
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<tr>
<td>17%</td>
<td>19.0c</td>
<td>40.6</td>
<td>35.3b</td>
<td>5.3a</td>
<td>0.36</td>
<td>1.49</td>
<td>20.2</td>
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<tr>
<td>21%</td>
<td>19.9b</td>
<td>40.6</td>
<td>36.9a</td>
<td>3.7b</td>
<td>0.35</td>
<td>1.63</td>
<td>20.2</td>
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<tr>
<td>25%</td>
<td>20.4a</td>
<td>40.7</td>
<td>37.7a</td>
<td>3.0c</td>
<td>0.38</td>
<td>1.65</td>
<td>20.2</td>
</tr>
</tbody>
</table>

No interactions
In general,
- For eggs of the same size, hatch time decreased when flock age increased.
- Increased oxygen conductance in eggs of older flocks increased HP.
- As a result, ET increased as well, which decreased hatch time!!
- What factor determines HP?
  - Energy utilization
  - Efficiency

\[
E_{YFB} = \frac{YFB (kJ)}{Albumen (kJ) + Yolk (kJ) - RY (kJ)} \times 100\%
\]
After Lourens et al. (2011).

<table>
<thead>
<tr>
<th></th>
<th>EST 37.8°C</th>
<th>EST 38.9°C</th>
<th>O₂ 17%</th>
<th>O₂ 21%</th>
<th>O₂ 25%</th>
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<td>Albumen (kJ)</td>
<td>73</td>
<td>76</td>
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<tr>
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<td>280</td>
<td>282</td>
<td>282</td>
<td>281</td>
<td>281</td>
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<tr>
<td>YFB (kJ)</td>
<td>170&lt;sup&gt;a&lt;/sup&gt;</td>
<td>158&lt;sup&gt;b&lt;/sup&gt;</td>
<td>150&lt;sup&gt;b&lt;/sup&gt;</td>
<td>172&lt;sup&gt;a&lt;/sup&gt;</td>
<td>171&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>RY (kJ)</td>
<td>48</td>
<td>46</td>
<td>68&lt;sup&gt;a&lt;/sup&gt;</td>
<td>43&lt;sup&gt;b&lt;/sup&gt;</td>
<td>31&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Utilized (kJ)</td>
<td>305</td>
<td>311</td>
<td>286&lt;sup&gt;c&lt;/sup&gt;</td>
<td>313&lt;sup&gt;b&lt;/sup&gt;</td>
<td>326&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>E&lt;sub&gt;YFB&lt;/sub&gt; (%)</td>
<td>55.7&lt;sup&gt;a&lt;/sup&gt;</td>
<td>50.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>52.5</td>
<td>54.9</td>
<td>52.4</td>
</tr>
<tr>
<td>HP at d18 (mW.egg⁻¹)</td>
<td>131&lt;sup&gt;b&lt;/sup&gt;</td>
<td>148&lt;sup&gt;a&lt;/sup&gt;</td>
<td>119&lt;sup&gt;c&lt;/sup&gt;</td>
<td>138&lt;sup&gt;b&lt;/sup&gt;</td>
<td>152&lt;sup&gt;a&lt;/sup&gt;</td>
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</table>

Energy utilization

<table>
<thead>
<tr>
<th>Energy utilization</th>
<th>E&lt;sub&gt;YFB&lt;/sub&gt;</th>
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<tbody>
<tr>
<td>Egg weight</td>
<td>Yes</td>
</tr>
<tr>
<td>Breed</td>
<td>Yes</td>
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<tr>
<td>Oxygen</td>
<td>Yes</td>
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<tr>
<td>Eggshell temperature</td>
<td>No</td>
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</table>
Environmental factors

**Eggshell conductance**

- Altitude
- Concentration
- Air pressure

Oxygen availability to the embryo (red blood cells)

Environmental factors: $\text{H}_2\text{O}$

- RH, MT, and conductance determine weight loss during incubation
- Development of air cell, required for internal pipping
- But focus on ET first…
- Ventilation early in incubation removes water from the machine
  - Not required
  - Creates cold spots
  - Spray nozzles / humidifiers to add moisture
  - High $\text{CO}_2$ level during week 1 stimulates development of membranes to support gas exchange later in week 3
  - High RH during week 1 needs to be compensated later
ET: balance between heat production and heat loss

Heat loss
- Evaporation
- Heat transfer
  - temperature difference
  - heat capacity
  - air velocity

Heat production
- Time / development
- Physical factors
- Biological factors
- Environmental factors

Embryo temperature (°C)
<table>
<thead>
<tr>
<th>Treatment</th>
<th>1-7 days</th>
<th>7-14 days</th>
<th>14-21 days</th>
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<tbody>
<tr>
<td></td>
<td>98</td>
<td>100</td>
<td>100</td>
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<tr>
<td>“multi-stage”</td>
<td>98</td>
<td>100</td>
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<tr>
<td>“single-stage”</td>
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<tr>
<td></td>
<td>100</td>
<td>100</td>
<td>102</td>
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Temperature values are egg shell temperatures.

Lourens et al, 2005

<table>
<thead>
<tr>
<th>Value</th>
<th>YFBM (g)</th>
<th>Length (cm)</th>
<th>%hatch</th>
<th>7 d b.w. (g)</th>
<th>Heart (g)</th>
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</thead>
<tbody>
<tr>
<td>98-100-100</td>
<td>37.1b</td>
<td>19.0ab</td>
<td>78.9a</td>
<td>147.7a</td>
<td>0.33ab</td>
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<td>98-100-102</td>
<td>33.8a</td>
<td>18.3a</td>
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<td>148.0a</td>
<td>0.28a</td>
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<tr>
<td>100-100-100</td>
<td>37.9b</td>
<td>19.4b</td>
<td>84.7b</td>
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<td>0.36b</td>
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<td>100-100-102</td>
<td>38.0b</td>
<td>19.3b</td>
<td>77.6a</td>
<td>151.9ab</td>
<td>0.31ab</td>
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</tbody>
</table>
Take home message:

Eggshell temperature is the key!!!
To know EST, you have to measure it
Keep EST close to 37.8°C constantly

Thanks for your attention!!