Is it possible to alleviate the negative effects of heat stress on reproduction of dairy cows?

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M.A. Driancourt, MSD Animal Health Innovation, France
Backbone of the presentation

- A brief introduction to heat stress
- When is heat stress reducing reproductive performance?
- Where is heat stress acting to affect reproductive performance?
- Why is heat stress reducing reproductive performance?
- What can we do to alleviate the heat stress effect?
  1. During the heat stress period
  2. During the carry over period
- Conclusions
A brief introduction to heat stress

How do the farmers see heat stress during the summer season?
- Cows produce less milk
- Cows eat less
- Cows are quieter
- Cows express shorter estrus periods with reduced mounting activity
- Fertility of cows following AI at detected heat is very low

A brief introduction to heat stress

Heat stress is evaluated by the temperature-humidity index (THI), that combines temperature and humidity.

\[
\text{THI} = (1.8T + 32) \times (0.55 - 0.0055RH) \times (1.8T - 26)
\]

![Diagram showing heat stress levels based on temperature and humidity.](image-url)
A brief introduction to heat stress

Conception rate starts declining when THI reaches 72, and collapses at higher THI values

Figure 1. Association between monthly average of daily maximum temperature-humidity index (THI) and conception rate for services

Morton et al 2007
A brief introduction to heat stress

Heat stress reduces fertility not only during the period of high heat and humidity, but also in the 2-3 months following this period (carry over effect).

End of the high heat period

Carry over effects of heat stress
= low fertility while temp is back to normal

Hansen & Arechiga
1999
When is heat stress reducing reproductive performance?

There are 2 periods in the cycle when heat stress has clear detrimental effects: the peri-ovulatory period and around luteolysis.

Figure 3. Fitted effects with adjustment for autocorrelation in heat load between days (using ridge regression) of 2 measures of heat load on conception rates in lactating dairy cows. The solid line is...
Where is heat stress interfering with reproduction?

- **Hypothalamo-pituitary axis**
  a. Altered amplitude of LH pulses (Gilad et al 1993)
  b. Reduced pituitary sensitivity to GnRH (blunted LH surge) (Gilad et al 1993)

- **Ovarian function**
  a. Altered follicular dominance (Wolfenson et al 1995)
  b. Reduced ability to convert androgens to estrogens (Wolfenson et al 1997)
  c. Reduced progesterone production by the CL (Wolfenson et al 2002)

- **Young embryo**
  a. Increased apoptosis (Roth & Hansen 2004)
  b. Impaired resumption of meiosis (Roth & Hansen 2005)
  c. Impaired oocyte cytoplasmic maturation, resulting in fewer blastocysts formed (Payton et al 2004)

- **Reproductive tract**
  a. Heat shock increases prostaglandin output by cultured endometrium collected on day 17 of the cycle (Malayer et al 1990) and increases uterine production of PGF2 alpha in response to oxytocin (Wolfenson et al 1993)
  b. Exposure of cultured day 17 conceptuses to 43°C reduces production of interferon tau, the embryonic signal that prevents luteolysis (Putney et al 1988)
Why is heat stress reducing reproductive performance?

**THE PRE-OVULATORY PERIOD**

- Aggravated negative energy balance
- High heat
- Reduced proliferation and maturation of follicular somatic cells
- Reduced androgen production by theca cells
- Reduced aromatization of androgens to estrogens (GC)
- Low estradiol output by the ovulatory follicle
- Reduced sensitivity of the pituitary to GnRH

**Short & shallow estrus**

**Delayed/blunted LH surge**
Why is heat stress reducing reproductive performance?

**THE POST-OVULATORY PERIOD**

- High heat

- Altered nuclear maturation of the oocyte
- Oocyte apoptosis
- Altered cytoplasmic maturation of the oocyte

- Reduced proportion of oocytes cleaving to reach the morula stage

- Reduced progesterone production by the CL

- Lower proportion of blastocysts formed

- Reduced growth rate of the blastocysts

- Small for age embryos at the time of luteolysis

- No pregnancy!
What to do to alleviate the effects of heat stress?

During the heat stress period

Cool and provide shade to the cows during the two periods when they are most sensitive to heat stress.
What to do to alleviate the effects of heat stress?

1. Use estrus synchronization to get around the estrus detection problems during the heat stress period.

GPG synchronization treatments are useful as they increase submission rates.

**Cumulative Frequency of Pregnancy Rates**

- **De la Sota et al 1998**

![Graph showing cumulative frequency of pregnancy rates over days postpartum with two curves, one labeled 'Control' and the other labeled 'II', and a note 'P < 0.01' indicating statistical significance.]
### What to do to alleviate the effects of heat stress?

2. **Inject GnRH at estrus to ensure a “normal” LH surge**

<table>
<thead>
<tr>
<th>Study Authors</th>
<th>Location and treatments</th>
<th>Group size</th>
<th>Fertility untreated group</th>
<th>Fertility treated group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ullah et al (1996)</td>
<td><strong>USA (MS)</strong>, 100µg GnRH at estrus synchronized by a prostaglandin vs neg control</td>
<td>49 treated &amp; 45 controls</td>
<td>17.9%</td>
<td>28.6%</td>
</tr>
<tr>
<td>Kaim et al (2003)</td>
<td><strong>Israel</strong> 10µg Buserelin vs neg control in PG synchronized cows</td>
<td>157 control &amp; 157 treated</td>
<td>35.1%</td>
<td>51.6%</td>
</tr>
<tr>
<td>Lopez-Gatius et al (2006)</td>
<td><strong>Spain</strong> 100µg GnRH at estrus vs neg control (all presynchronized)</td>
<td>429 treated &amp; 431 controls</td>
<td>20.6%</td>
<td>30.8%</td>
</tr>
</tbody>
</table>
What to do to alleviate the effects of heat stress?

3. Inject GnRH to alter follicular turnover (days 5 and 11) and possibly postpone initiation of the luteolytic cascade (day 11) (Willard et al 2003)

<table>
<thead>
<tr>
<th>Treatment Location</th>
<th>USA (MS &amp; NC)</th>
<th>N=</th>
<th>Fertility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>Ovsynch synchronized</td>
<td>37</td>
<td>19%</td>
</tr>
<tr>
<td>GnRH Day 5</td>
<td>As above + 100µg GnRH</td>
<td>34</td>
<td>32%</td>
</tr>
<tr>
<td>GnRH Day 11</td>
<td>As above +100µg GnRH</td>
<td>34</td>
<td>38%</td>
</tr>
</tbody>
</table>
4. Inject GnRH on days 0 and again around day 12 to combine the benefits of the two previous approaches.
What to do to alleviate the effects of heat stress?

During the heat stress period

**PROVIDE MAXIMAL SHADE, COOL & TRY TO BE SMART...**

1. Selectively breed the heifers during the heat stress period
2. Use embryo transfer to breed the lactating cows

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**Figure 1.** Conception rate of cows in AI, ET-DON, and ET-IVF groups determined by palpation per rectum at 42 days after estrus.

The conception rate at 42 days was higher (P<0.05) in cows in the ET-DON group than those in ET-IVF. Conception rates of the AI versus ET- (DON and IVF) did not differ (P>0.10).

AI = artificial insemination. ET-DON = embryo transfer (embryos collected from superovulated donors), ET-IVF = embryo transfer (embryos produced in vitro).

*Drost et al 1999*
What to do to alleviate the effects of heat stress?

As none of these treatments will stop the effects of heat on the oocytes, do not expect miracles from such treatments

During the heat stress period

Further research is needed to identify strategies whereby the young embryos (before genome activation) may be made tolerant to heat!
What to do to alleviate the effects of heat stress?

1. Remove the heat damaged follicles by follicle aspiration (Wolfenson et al 2001)

2. Accelerate follicle turn over by injection FSH to deplete the ovary from heat stressed follicles (Roth et al 2002)

However, none of these approaches is easy and has gained acceptance in field conditions...

AND

Further research is needed to understand the delayed effects of heat on oocyte and follicle quality
Conclusion (1)

Heat stress is a very complex problem that warrants further research.
Conclusion (2)

Multi-disciplinary research is needed to devise improved solutions

Understanding of the appetite-metabolic balance-heat stress interactions

Understanding of the lactation-heat stress interactions

Understanding of reproduction - heat stress interactions

Understanding of the effects of heat stress of pregnant cows on their progeny

Understanding of the genetics-reproduction interactions in breeds tolerant to heat stress