In the Spotlight

* Is high ambient temperature really affecting reproductive efficacy in cattle?
* How to measure the intensity of heat stress in field conditions
* Mechanisms through which heat stress impairs reproduction in dairy cows
* Management of reproduction in dairy herds exposed to high ambient temperatures:
  * cooling
  * estrus synchronization
  * embryo transfer

GETTING COWS PREGNANT WHEN IT’S HOT – A GROWING PROBLEM WITH SOME NOVEL SOLUTIONS

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How Heat Stress Affects Reproduction

A cow’s ability to express its genetic potential for milk production, reproduction, and health depends upon her environment. If environmental conditions are not optimal, performance will be lower than could otherwise be expected. Heat stress is one environmental factor that can cause large decreases in milk yield and reproduction.

Dairy cow reproduction declines during heat stress in two ways. The intensity of estrus is less during heat stress so estrus detection becomes difficult. Secondly, fertility following insemination is reduced.

The magnitude of heat stress effects varies between regions of the world. In a location like Florida, where heat stress is severe because of the combined effects of elevated air temperatures, high humidity, and intense solar radiation, estrus detection rates during the summer can be 20% and pregnancy rate per AI (the proportion of inseminated cows that became pregnant) can be 10-20%. Even in a cool climate, heat stress can occur in summer. In a recent study in Alberta, Canada, the pregnancy rate per AI was lower for cows during the summer (23%) than for other seasons (32%) (Ambrose et al., 2006).

The fact that fertility declines in the summer as far north as Alberta highlights one of the most important features of the problem – heat stress affects most dairy cows and not only those who live in hot climates.

Effects of heat stress on reproduction are closely tied to the increase in body temperature that heat-stressed cows experience. Body temperature increases during heat stress when the cow cannot lose all of its heat of metabolism to the surrounding environment. An increase in uterine temperature of 0.5°C above average is associated with a decline in conception rate of 12.8% (Gwazdauskas et al., 1973).

An example of the effect of air temperature on rectal temperatures of lactating cows and non-lactating heifers is illustrated for animals in Wisconsin in Figure 1. Note that for lactating cows, body temperature becomes high enough to compromise fertility at relatively mild temperatures. At an air temperature of 28°C, for example, predicted cow body temperature was about 39.6°C or approx. 1°C above body temperature in the absence of heat stress.

Examination of Figure 1 also reveals that heifers exposed to high air temperatures have much lower rectal temperatures than lactating cows. This difference exists because heifers, which are not lactating, produce less heat of metabolism than cows. Not surprisingly, heifers are much more resistant to the adverse effects of heat stress on reproduction than lactating cows.
Cows that produce more milk generate more heat of metabolism. Accordingly, high-producing cows can be more susceptible to heat stress than cows producing less milk. The data in Figure 2 illustrate how the magnitude of the summer decline in fertility depends on milk yield. In this study, conducted in Florida and Georgia in the southern United States, fertility was measured indirectly by the 90-day non-return rate (the proportion of cows that are not detected in estrus within 90 days after insemination). The 90-day non-return rate declined in the summer and the magnitude of the decline was greatest for cows producing more than 9072 kg/lactation, intermediate for cows producing between 4526-9072 kg and lowest for cows producing less than 4536 kg.

Much has been made of the reduction in dairy cattle fertility in the last 50 years. Some of the fertility loss has probably occurred because the increase in milk yield during this time has increased cow sensitivity to heat stress. Such seems to have been the case in northeastern Spain between 1991 and 2000 (Figure 3). During this time, milk yield increased over 30%. There was no decrease in first service pregnancy rate per AI during the cool season but pregnancy rate in the warm season declined from 36.4% in 1991 to 22.1% in 2000.
How to Measure Heat Stress

The best way to determine whether cows are suffering from heat stress is to measure rectal temperature. Normal body temperature of the cow is about 38.6°C (101.5°F). One should be concerned if rectal temperature in the afternoon is higher than 39.0°C (102.2°F) in otherwise healthy cows. When rectal temperatures are greater than 39.5°C (103.1°F), it is very likely that cows are heat stressed to the point where large declines in milk production and reproduction occur.

Measurements of rectal temperature should be taken in the afternoon when cows are most likely to be experiencing elevated body temperature. Temperature should not be measured when cows are in the parlor area where they may have been cooled by udder washers, fans or sprinklers. Also, rectal temperatures will not be too informative if cows had to walk a long way before measurements were made or cows were stressed when restrained for temperature measurement.

The thermometer should be placed in the rectum for a full minute to give the thermometer time to stabilize. While waiting, one can quickly measure respiration rate by counting the number of times the flank moves in a minute. Cows breathing more than about 60 times a minute are likely to be suffering from heat stress.

Heat stress can also be estimated by measuring meteorological variables. This approach is not as accurate at determining heat stress as direct measurements of rectal temperature. This is so because elevation in body temperature during heat stress is determined by a variety of meteorological variables (air temperature, humidity, solar radiation, and wind speed), other features of the environment (amount of shade, reflectivity of the ground and roof for solar radiation, etc.), and features of the cow (such as coat color and level of milk production).

A cow’s thermal balance is determined by the gradient between air temperature and skin temperature, the amount of solar radiation striking the cow’s surface and the humidity in the air. Humidity is important because cows lose heat by evaporating water from the skin (via sweating) and lungs (via panting). When humidity is high, the amount of water loss via sweating and panting is reduced.

A term called the temperature-humidity index (THI) that combines dry bulb temperature and humidity has been used to estimate heat stress. When air temperatures are measured in degrees Celsius (T) and relative humidity is abbreviated as RH, the THI is calculated as:

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

Heat stress is usually considered a problem when the THI is above 72 and severe heat stress to exist when the THI is over 76.

A simple way to estimate heat stress is to measure air temperature (also called dry bulb temperature). Unpublished data from our laboratory indicates that in Florida, where humidity is usually high, air temperature is nearly as accurate as THI or combinations of air temperature with other meteorological variables in predicting cow body temperature (Serdal Dikmen and Peter Hansen, unpublished).
Why Heat Stress Affects Fertility

To develop useful strategies for reducing effects of heat stress, it is necessary to understand why heat stress reduces fertility. Heat stress affects cow performance in two ways. First, some of the physiological adjustments cows undergo to regulate body temperature during heat stress can compromise physiological functions required for optimal milk yield and reproduction. For example, blood flow to the skin is increased during heat stress to increase heat loss to the environment. As a result, blood flow to other organs including the mammary gland and reproductive tract is reduced. Secondly, the elevation in body temperature caused by heat stress can itself compromise cellular function. This effect of heat stress is one of the causes of infertility because development of embryos at early stages of pregnancy is disrupted at elevated temperatures.

The fate of a newly-produced embryo depends to a significant extent on the health of the oocyte from which it was derived. If the oocyte was not formed properly, or experienced some stress during its formation, it is likely that the resultant embryo will experience abnormal development and early death. A key point to consider is that the oocyte that ovulates today comes from an ovarian follicle that initiated growth about 3 months previously. During this time of growth and development, heat stress can compromise follicular function. Follicular estradiol production has been reported to be compromised by heat stress. In addition, heat stress can reduce follicular dominance so that the follicle emerges from the growing pool at an early stage and the ovulation oocyte may be aged somewhat (note that despite the reduction in follicular competence, there is little evidence for increased double ovulations during heat stress).

It is not clear how soon before ovulation heat stress can actually compromise the follicle and its enclosed oocyte. Results from a study in Israel suggests that heat stress can affect follicular production of steroid hormones 20-26 days later (Roth et al., 2001a).

There are two consequences of the fact that heat stress can damage the follicle weeks before ovulation. First, one cannot improve fertility to a large degree by cooling cows for a few days around the time of insemination. Damage to the oocyte by heat stress has already occurred by the time the cow is inseminated. Second, fertility is not restored immediately after the end of heat stress but rather only when follicles damaged during heat stress have been removed as part of the process of normal process of follicular growth and regression. In Israel, this delay in restoration of oocyte quality in the autumn could be shortened by increasing follicular turnover using ultrasound-guided aspiration of follicles, or treatment with FSH or bovine somatotropin (Roth et al., 2001b; Roth et al., 2002). While not yet evaluated, perhaps it will be possible to improve fertility in the autumn through hormonal treatments that cause follicle turnover.

Heat stress around the time of ovulation can also compromise fertility. Thereafter, sensitivity to heat stress changes as embryonic resistance to heat stress changes. In a study with superovulated cows, it was shown that heat stress at Day 1 after insemination reduced embryonic survival but heat stress at Day 3, Day 5 or Day 7 after insemination had no effect on embryo survival (Ealy et al., 1993). In vitro, the embryo is less susceptible to undergo disruption in development caused by elevated temperature as it advances in development. By the time it reaches the...
morula stage (Day 4-5 of pregnancy), it is much more resistant to elevated temperature than embryos at earlier stages. Heat stress can still compromise embryonic development after Day 4-5 and can also sometimes cause a reduction in circulating concentrations of progesterone. However, the impact of heat stress on embryonic survival is reduced as compared to earlier in pregnancy.

Shown in Figure 4 is a timeline of reproductive events affecting pregnancy establishment and the impact of heat stress on these events. From this drawing it is apparent that achieving high fertility during heat stress depends upon preventing damage to 1) the follicle and oocyte before fertilization and 2) the early embryo after heat stress. Moreover, if the embryo can be protected from heat stress during the first few days of life, it will be substantially resistant to heat stress thereafter.

Even after pregnancy is established, significant pregnancy loss in dairy cattle occurs: about 10% of pregnancies at Day 40-50 result in fetal loss. In a study in Spain, cows that experienced a higher THI between Days 21 and 30 of gestation were more likely to experience pregnancy loss between Day 43 and 48 of gestation and Day 90 of gestation (García-Ispierto et al., 2006). Heat stress in late gestation can also compromise fetal growth and calf birth weight and reduce subsequent milk yield.

How to Improve Reproduction during Heat Stress

Not by cooling alone......
There are many housing systems that can be used to reduce heat stress in dairy cows as illustrated in Figure 5. Some are expensive and probably only practical in regions where heat stress is a continual and severe problem. Even extensive cooling systems may not prevent seasonal depression in fertility.

One common system for cooling cows is based upon the use of sprinklers and fans in free stalls or loose housing. Sprinklers often are programmed to be on for 3-5 minutes of a 15-minute cycle and are located so as to avoid wetting feed or loafing areas. Cooling occurs because water striking the cow is evaporated in a process that removes heat from the cow. Other systems, such as the CowKool® system marketed in Israel, use foggers that direct their output into high-capacity fans to cool the air that passes over cows.

The most recent development in cooling cows is the advent of tunnel ventilation and cross-ventilation barns. In these very-expensive systems, air is pulled through the end (tunnel ventilation) or side of the barn (cross ventilation) via a bank of exhaust fans. These barns typically have a low roof and enclosed sides and can also include foggers or misters to promote evaporative cool-
Cooling is more effective at increasing milk yield than it is at improving fertility. In the coastal area of Israel, implementation of intensive cooling systems has greatly reduced the summer depression in milk yield. Flamenbaum and Ezra (2006) found that the ratio of summer milk yield to winter milk yield in intensively cooled herds was 96-103% of that in summer. However, conception rate for high-producing herds was only 19% in summer as compared to 39% in winter. For lower-producing herds, conception rate was 25% in summer as compared to 40% in winter. In Florida, too, fertility declines even in herds where cows are cooled with sprinklers and fans (see Figure 6).

**Heat stress effects on estrus detection can be eliminated**

The advent of timed artificial insemination techniques such as OvSynch and similar procedures has made it possible to eliminate the problem of estrus detection caused by heat stress. As a result, timed AI can increase the proportion of cows in the herd that are pregnant even during the summer. In a Florida herd with a voluntary waiting period of 70 days, for example, the percentage of cows that were pregnant by 90 days postpartum was 16.6% for cows in which first insemination was via OvSynch vs 9.8% for cows inseminated at visual estrus detection only (Aréchiga et al., 1998).

The increase in pregnant cows during heat stress caused by OvSynch is a result of an increase in the proportion of eligible cows that are inseminated and not an increase in fertility. In the Florida herd, for example, the percent of inseminated cows that became pregnant at first service was 13.6% for cows bred after Ovsynch and 12.5% for cows bred at visual estrus.

Bulls are often used to increase reproductive success in dairy cattle. One apparent advantage is that bulls are better at detection of estrus than humans. However, the bull is also susceptible to heat stress and decreased libido and reduced semen quality can result. Analysis of records in Florida and Georgia indicated that the proportion of eligible cows in a 21-day period that were pregnant was slightly higher for herds bred by bulls as compared to herds bred by AI in the summer (9.8% vs. 8.1%) but not in the winter (18.0% vs. 17.9%) (de Vries et al., 2005).

**AI versus embryo transfer**

A variety of drugs have been administered after AI in an attempt to increase fertility. Examples include GnRH, bovine somatotropin and human chorionic gonadotropin. Unfortunately, no drug has proven to be consistently successful in improving fertility of heat-stressed cows when administered after breeding (Table 1). The hormonal treatment with the greatest recorded benefit for increasing pregnancies in heat-stressed cows is two injections of GnRH at insemination and 12 days later (López-Gatius et al., 2006; see Table 1). There is a need to repeat this successful result before a general recommendation can be made.
Table 1. Some examples of experiments to test hormonal treatments for improving fertility of lactating cows during heat stress.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Location</th>
<th>Response measured</th>
<th>Control group</th>
<th>Treated group</th>
<th>Notes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>GnRH at Day 14 or 15 after insemination</td>
<td>Florida</td>
<td>Percent of cows inseminated at detected estrus that were pregnant at ~ 45 days after</td>
<td>25.6%</td>
<td>20.5%</td>
<td>4 experiments conducted with heat-stressed cows; GnRH increased fertility in 1 of 4</td>
<td>Franco et al., Theriogenology 66:945 (2006)</td>
</tr>
<tr>
<td>GnRH at insemination and 12 days later</td>
<td>Spain</td>
<td>Percent of cows inseminated at detected estrus that were pregnant at 38-45 days after AI (n=860)</td>
<td>20.6</td>
<td>35.4***</td>
<td>GnRH at insemination =30.8% pregnancy rate</td>
<td>L.opez-Gatius et al., Theriogenology 65:820 (2006)</td>
</tr>
<tr>
<td>Human chorionic gonadotropin at Day 5 or 6 after AI</td>
<td>Florida</td>
<td>Percent of cows inseminated at first service that were pregnant at 45-60 days after AI (n=201 cows total)</td>
<td>24.2%</td>
<td>23.5%</td>
<td>Bred at detected estrus</td>
<td>Schmitt et al., J. Anim. Sci. 74:1074 (1996)</td>
</tr>
<tr>
<td>Human chorionic gonadotropin at Day 5 after AI</td>
<td>California</td>
<td>Percent of cows inseminated at first service that were pregnant at 28 days after AI (n=182 cows total)</td>
<td>44.1%</td>
<td>43.3%</td>
<td>Bred at detected estrus; hCG was effective in cool weather (47.8 vs. 34.2%)</td>
<td>Santos et al., J. Dairy Sci. 79:2881 (2001)</td>
</tr>
<tr>
<td>Bovine somatotropin every 2 weeks beginning 1 week before Ovsynch initiation</td>
<td>Georgia</td>
<td>Percent of cows inseminated at first service (Ovsynch) that were pregnant at 40-80 days after AI (n=276)</td>
<td>15.2%</td>
<td>16.7%</td>
<td></td>
<td>Jousan et al., J. Dairy Sci. 90:341 (2007)</td>
</tr>
</tbody>
</table>

* Control vs treated, P<0.0001
The lack of success of hormonal treatments for improving fertility during summer means that the only option for improving fertility of heat-stressed cows bred by AI is to implement a cooling scheme. If breeding practices are not limited to AI, however, another strategy exists to improve fertility during heat stress. In fact, embryo transfer can reliably increase pregnancy success in lactating cows exposed to heat stress.

Embryo transfer improves fertility during heat stress because embryos are typically transferred into the uterus of recipient cows at Day 6-8 after estrus when the embryo has already passed the period when it is most susceptible to elevated temperature (see Figure 4). Moreover, embryos used in embryo transfer have also escaped damaging effects of heat stress earlier in embryonic development or on the oocyte.

The effectiveness of embryo transfer for improving fertility has been most clearly shown in an experiment in Brazil. In that study, lactating Holstein cows were either inseminated or received a superovulated embryo. As seen in Figure 7, the decline in fertility in the summer seen in inseminated cows did not occur in embryo transfer recipients. There was no difference in pregnancy rate between AI and ET in cool months but pregnancy rate was higher in ET recipients than in inseminated cows in hot months.

Reduced expression of estrus in heat-stressed cows can make embryo transfer difficult. Fortunately, it is possible to get good pregnancy rates by performing timed embryo transfer. With this procedure, ovulation is synchronized using Ovsynch or another procedure and embryos are transferred to recipients 7 days after the time insemination would ordinarily be performed.

Figure 7. Seasonal variation in pregnancy rates (number pregnant/number inseminated or receiving an embryo) in Brazil for lactating Holstein cows that were either inseminated (AI) or received a fresh or frozen-thawed embryo produced by superovulation. Months in which the average ambient air temperature was less than 22.5°C are shown with the gray bar. Asterisks indicate significant differences between AI and ET. Data are redrawn from Rodrigues et al. (2004) and reproduced from Hansen (2006b).
References


In the next issue

Reproduction success is undoubtedly one of the most important determinants of profitability for any dairy operation, regardless of the geographical location. Increasing milk production, progress in automation of production as well as growing cost of labour and feed are but some of the factors that make reaching ambitious goals of reproduction management in a dairy herd fairly difficult. In the next issue of the Intervet Reproduction Newsletter we present an article by Professor Gert Opsomer, that aims to provide veterinary practitioners with some recent knowledge and insights about fertility and fertility problems in modern high yielding dairy cows. Moreover the author discusses practical applications of such novel solutions and systems in reproduction management in a modern dairy herd.