Managing the Heat-Stressed Cow to Improve Reproduction

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The Growing Problem of Heat Stress

A high-producing cow starts to experience an increase in body temperature at air temperatures as low as 80°F. As a result, heat stress is a problem throughout most of the country, even in places as far north as Wisconsin. Cows that are exposed to heat stress suffer decreased feed intake, reduced milk yield, poor expression of the signs of estrus, and infertility.

Cows experience an increase in body temperature in hot weather because they cannot lose all of the body heat they produce to the environment. High-producing cows produce more heat than low-producing ones and, therefore, the effects of heat stress increases as milk yield increases. This idea is illustrated in Figure 1 which depicts seasonal variation in 90–day non-return rate (an estimate of conception rate) for cows in Florida and South Georgia. Note that the summer-depression in fertility is greater, and lasts for more months, for cows producing between >20,000 lb of milk per lactation than for cows producing less between 10,000-20,000 lb of milk. The summer depression in fertility is small for cows producing less than 10,000 lb of milk.

What this means is that as we continue to increase milk yield (by genetic selection, improved feeding practices, etc.), we will be making cow more susceptible to heat stress. Much has been made of the fact that the dairy cow is less fertile today than is was 20 or 30 years ago. At least part of this decline is because cows are more susceptible to heat stress than they were before. Reducing the impact of heat stress on reproduction is one way to reverse some of this historical decline in dairy cow fertility.

Going Beyond Cooling the Cow

In places like Florida and Arizona, where heat stress is a continual and severe problem, the most common approach that dairy farmers have taken to minimize effects of heat stress has been to modify housing to cool the cow. The optimal use of such modifications of dairy cow housing as shade, sprinklers, fans, and misters is beyond the scope of this paper. Three points are relevant, however. First, cooling cows can be an important way to reduce effects of heat stress on milk yield and reproduction and should be incorporated into dairy housing systems when feasible. Second, there is ongoing research into use of new cooling methods such as tunnel ventilation that may prove more effective than existing systems that focus on fans in combination with sprinklers and sprayers. Finally, cooling systems do not usually eliminate the seasonal depression in fertility, at least in places like Florida where heat stress can be severe. The last point is illustrated by data in Figure 2 that show monthly variation in conception rates for a 2000-head unit in South Florida in which cows were housed in freestalls with sprinklers and fans. Note that the use of these cooling aids did not prevent a large decline in conception rates during the summer.

The inability of current cooling systems to eliminate the summer depression in reproduction means that it is useful to have other approaches for improving reproduction during heat stress. This paper will focus on approaches for improving reproduction in the summer that are based on overcoming changes in the cow's physiology that are disrupted by heat stress.

Aspects of Reproduction Disrupted by Heat Stress

Simply put, it is difficult to get cows pregnant during heat stress because 1) it is hard to see cows in heat and 2) even if heat is detected, few cows conceive after insemination.

Detection of estrus is not easy even in the absence of heat stress. Using the HeatWatch® patches to record each time a cow is mounted, researchers at Virginia Tech University have estimated that estrus in the lactating dairy lasts only 7-10 hours. During that time, cows are mounted an average of 8-10 times. The total amount of time spent being mounted (calculated as the number of mounts times the amount of time being ridden) is only about 24 seconds. Compounding the problem is the fact that estrus gets shorter in length as milk yield goes up. An important point to consider is that cows that show a weak estrus (in other words, don't get mounted many times or exhibit estrus for very long) are just as fertile as cows that are very active sexually during estrus (see Table 1). Thus, failure to identify cows with poor symptoms of estrus has just as much effects on the subsequent herd conception rate as failure to identify a cow with very intense sexual behavior.

Table 1. Effect of intensity of estrus on conception rates in lactating cows.[1]

Category of estrus [2]	Percent of cows in that category	Conception rate (%)
Low intensity-short duration	24.1	45.6
Low intensity-long duration	33.2	45.5
High intensity-short duration	34.3	47.0
High intensity-long duration	8.4	49.8

1 From Dransfield et al., J. Dairy Sci. 81, 1874-1882 (1998)

Given this cow behavior, it is not surprising that so many heats are not detected. In a study in Florida, for example, over 40% of the estrus periodss were missed in the best months (Figure 3). In the worst months, those associated with heat stress, 75-80% of the estrus periods were missed. The difficulty in detecting estrus in the summer is because heat stress reduces both the length of time that a cow is in estrus as well as the number of mounts.

The other major effect of heat stress on reproduction is a reduction in the proportion of cows that become pregnant after insemination. This effect has already been illustrated in Figures 1 and 2. The magnitude of the summer depression in fertility can be large - conception rates of 10% or less are common during the summer in Florida.

There are multiple causes for the poor fertility during heat stress. One action of heat stress is to disrupt the function of the follicle - the structure where development of the egg (or oocyte) takes place. As a result, heat-stressed cows tend to produce oocytes that have reduced capability of becoming fertilized and, if fertilization does take place, of becoming embryos capable of normal development. Cows exposed to heat stress typically have elevated body temperatures that are high enough to damage the oocyte directly and also to kill the embryo. Finally, the blood levels of the hormone progesterone, which is responsible for maintaining pregnancy, can be reduced in heat stressed cows.

How Hot is Too Hot?

In a place like Florida, it is not too difficult to determine when the weather is likely to cause the cow to be heat stressed. Almost every day in the summer is hot enough to compromise reproduction and decrease milk yield. In other environments, it is less obvious whether the weather is hot enough to affect the cow adversely. Accordingly, a variety of indices have been developed to help predict whether cows are under heat stress. The most common of these is the temperature-humidity index which is calculated from the air temperature and relative humidity. These indices only provide a rough indication as to whether the cow is heat stressed. That is so because a cow's body temperature depends on other environmental variables in addition to air temperature and humidity, especially wind speed and solar radiation. In addition, cow factors determine the magnitude of the increase in body temperature experienced during heat stress. High-producing cows tend to be more affected by heat stress than low-producing cows, black cows are more sensitive than white cows, and BST can increase susceptibility to heat stress.

The best way to determine how badly cows are being affected by heat stress is to measure the rectal temperature. Normal body temperature of the cow is about 101.3°F. It has been shown that an increase in body temperature of about 0.9°F causes a decline in conception rate of 12.8% [Gwazdauskas et al., J. Dairy Sci. 56, 873-877 (1973)]. One can consider that a cow that has a rectal temperature of about 102.2°F or higher in the afternoon is likely to be heat stressed (if she does not have mastitis or is otherwise sick). Determining rectal temperatures on groups of cows in the afternoon can be a quick way to get an accurate assessment of the degree of heat stress and the effectiveness of any cooling systems incorporated into cow housing.

Minimizing the Impact of Heat Stress on Detection of Estrus

Fortunately, there are several techniques available for overcoming the effect of heat stress on detection of estrus. One approach is to incorporate one of the many estrus detection aids available. The simplest of these is chalk applied to the tailhead. Rubbed-off chalk indicates the cow was in estrus. The effectiveness of chalking the tail was demonstrated in an experiment conducted in the summer in South Florida with lactating cows. The percentage of cows detected in estrus after estrous synchronization using Lutalyse® was 26% based on visual detection only versus 43% based on visual detection was combined with tail chalk [Ealy et al., J. Dairy Sci. 77, 3601-3607 (1994)].

A variety of tailhead patches for detection of mounts are also sold . These include the KaMar®, Bovine Beacon® and Estrus Alert™ patches. The HeatWatch® system is the most sophisticated device to measure mounting behavior. It consists of a pressure transducer applied to the tailhead inside a large glued-on patch. Each time the cow is mounted, information is sent to a computer recording the time and duration of the mount. This system is the gold standard for estrus detection but is also very expensive. Cows that wear the HeatWatch patch for a prolonged time can experience tissue irritation and damage underneath the patch.

Other remote systems for estrus detection use pedometers to measure the number of steps cows take. These devices are based on the fact that cows in estrus spend more time walking than other cows. There is still a shortage of data regarding how well these systems work in facilitating estrus detection.

Development of timed artificial insemination protocols such as the OvSynch procedure make it possible to avoid the need for estrus detection and inseminate cows at a fixed time. Use of OvSynch in heat stressed cows has been shown to increase the rate at which cows get pregnant after calving. In a Florida herd with a voluntary waiting period of 70 days, the percentage of cows that were pregnant by 90 days postpartum was 16.6% for cows in which first insemination was via timed artificial insemination using OvSynch vs 9.8% for cows bred based on visual estrus detection only [Aréchiga et al., J. Dairy Sci. 81, 390-402 (1998)].

In a Kansas study [Cartmill et al., J. Dairy Sci. 84, 799-806 (2001)], cows in the summer were inseminated between 50 and 70 days in milk using one of two breeding protocols. One group was timed inseminated following the OvSynch protocol. The other group was inseminated after a detected estrus induced by an estrous synchronization protocol (GnRH followed 7 days later by Lutalyse). All of the OvSynch cows were inseminated vs 58.7% of cows subjected to estrous synchronization. There was no difference in conception rate between the two groups (33.3% for OvSynch vs 32.0% for estrous synchronization) but because more cows were inseminated, the proportion of cows pregnant using ultrasound diagnosis at day27-30 of gestation was greater for the OvSynch group (33.3% vs 16.7%). In this study, the pregnancy loss after day 27-30 was greater for the OvSynch group so overall pregnancy rates at day 40-50 were similar between the two groups (16.4% for OvSynch vs 13.3% for estrous synchronization).

Is it economical to use timed artificial insemination during heat stress? This is an important question because timed artificial insemination works by increasing the number of cows inseminated and not by reducing the effects of heat stress on fertility. Semen and drug costs are incurred for all cows subjected to timed artificial insemination and the fact that cows are heat stressed means that only a small fraction of cows will become pregnant. There has not been a detailed economic analysis of the benefits of timed artificial insemination during heat stress. However, it makes sense that timed artificial insemination is more valuable on farms where estrus detection is poor.

Improving Fertility in Cows Subjected to Artificial Insemination

If we could find a way to increase the conception rate of heat-stressed cows, timed artificial insemination would be a very practical system during the summer. In fact, however, the only known method for increasing fertility in heat-stressed cows is to cool the cow. A wide variety of hormonal treatments have been tested for increasing fertility of heat-stressed cows but none of them have been shown to consistently cause an increase in fertility of heat-stressed cows. Until such a treatment is developed, it will be difficult to achieve optimal conception rates following artificial insemination in heat-stressed cows.

Can Using a Bull Help?

The proportion of cows inseminated artificially in the United States declines during the summer months. In part, this may reflect unwillingness to use semen (which is relatively expensive) during times of the year when fertility is low. There is also interest in bull breeding to help solve reproduction problems. One obvious advantage to using bulls during heat stress is that bulls are better at detection of estrus than humans. Keep in mind, though, that the bull is susceptible to heat stress just like the cow. The bull probably does not get as hot as the lactating cow because its metabolism is lower. However, when heat stress gets severe enough, it can cause decreased libido in the bull and a decline in semen quality that persists for about two months after the end of heat stress. The lag in restoration of fertility after heat stress is the result of damage to the precursor cells for spermatozoa. There are no experimental data regarding whether use of bulls actually increases the proportion of cows that get pregnant during heat stress. It makes sense, though, that the benefits of the bull will be limited when heat stress is severe enough to affect the bull's body temperature.

Embryo Transfer as a Tool to Improve Pregnancy Rate

Earlier, it was mentioned that one of the causes of infertility in the summer is the lethal effects of elevated body temperature on the oocyte and embryo. One of the features of embryonic development is that embryos become more resistant to various stresses as they become older. Thus, heat stress on the day after breeding can block embryos from developing while heat stress at seven days after breeding has little effect on embryonic survival. The use of embryo transfer to improve fertility in the summer is based on the fact that embryos are typically transferred into the uterus of recipient cows at day 7-8 after estrus, a time when the embryo has already passed the period when it is most susceptible to elevated temperature (see Figure 4). Effects of heat stress on the oocyte are avoided because the only embryos transferred are those derived from oocytes with sufficient quality to give rise to transferable embryos. Embryos can also be produced during cool months of the year, when the oocyte is not susceptible to heat damage, and then frozen until transfer in the summer.

Pregnancy rates in lactating cows exposed to heat stress can be improved as compared to artificial insemination. The source of embryo, though, has a major effect on the success rate. The best embryos that can be transferred in terms of chances of establishing pregnancies are embryos produced by superovulation. In this procedure, donor cows are treated with multiple injections of follicle-stimulating hormone to cause growth and ovulation of multiple follicles. As shown in Figure 5, transfer of fresh (i.e., non-frozen) embryos from superovulated cows into heat-stressed recipients improved pregnancy rates from 13.5% for artificial insemination to 29.2% for embryo transfer. An increase in pregnancy rate using superovulated embryos is also seen when superovulated embryos are transferred after long-term storage by freezing. In particular, it was found that pregnancy rate for artificial insemination was 24.1% vs 35.4% for cows receiving a frozen-thawed superovulated embryo.

Embryo Transfer Using Embryos Produced In Vitro

Superovulation is a time consuming and expensive procedure. Generally, 4-8 transferrable embryos are produced per superovulation procedure at a cost of about $75-125 per embryo. Donor cows can be used no more frequently than once a month and, more commonly, less often. Another method for producing embryos is through in vitro fertilization (IVF). In this procedure, oocytes recovered from donor cows are fertilized in the laboratory. Oocytes can be recovered from living donors using a procedure called transvaginal, ultrasound-guided, oocyte recovery (or oocyte pickup or OPU for short). One advantage of OPU over superovulation is that the procedure can be produced as often as twice weekly and can be performed on pregnant cows as well as open cows. Oocyte pickup is an expensive procedure, however. A typical fee for a single collection (yielding 1-2 transferrable embryos) is $400. Moreover, OPU requires highly skilled personnel and specialized equipment. OPU is best used when the goal is to obtain offspring from valuable donor cows.

An alternative IVF procedure is to harvest oocytes from ovaries collected at a slaughterhouse. While the identity of the donor animal is not known, the cost of producing embryos from slaughterhouse oocytes is relatively cheap. Estimates for commercial production of embryos using slaughterhouse oocytes is about $15 to $30 per embryo. Among the companies that will produce embryos using slaughterhouse oocytes are BOMED (Madison, WI) and Transova (Sioux Center, Iowa)

The genetic value of embryos produced by slaughterhouse embryos can be high. It has been shown that the predicted transmitting ability for milk yield for cows sent to slaughter is only slightly less than the overall population of cows. Moreover, since one straw of semen can be used in IVF to produce dozens of embryos, embryos of high genetic potential can be produced inexpensively. When sexed semen comes on the market, its use can be incorporated into IVF systems to produce large numbers of female embryos inexpensively.

Like for superovulated embryos, pregnancy rates in the summer can be improved by transferring embryos produced in vitro to cows (see Figure 4).   However, in vitro produced embryos do not survive freezing as well as embryos produced by superovulation and the increase in pregnancy rate achieved by transfer of embryos produced in vitro is only seen when fresh embryos are transferred (Figures 3-4). Pregnancy rates achieved following transfer of a frozen-thawed embryo produced in vitro were no higher than what is achieved by AI.

Problems with Embryos Produced In Vitro

The inexpensive cost of embryos produced using slaughterhouse oocytes make them a compelling choice for embryo transfer schemes whose primary purpose is to increase fertility during summer. It is important to remember, however, that there are additional problems associated with the use of these embryos. In addition to not freezing well, a high rate of fetal loss has been reported following transfer of embryos produced in vitro. In our hands [Block et al., J. Anim. Sci. 81, 1590-1603 (2002)], 24% of cows pregnant at day 53 of pregnancy lost their pregnancy before calving. This compares to a value of about 10% for lactating cows bred via artificial insemination. There can also be a higher incidence of prenatal mortality associated with calves produced by in vitro fertilization. Calves produced from in vitro produced embryos also tend to be larger at birth - in our system, Holstein calves produced from in vitro-produced embryos weighed an average of 94 lb at birth. Occasionally, very large calves (as much as 200 lb) can be born. The occurrence of these grossly oversized calves is less frequent than was previously the case because of changes in culture conditions (removal of serum from the growth medium used to produce embryos).

In many culture systems used to produce embryos, a greater proportion of transferrable embryos are male. In our last study [Block et al., J. Anim. Sci. 81, 1590-1603 (2002)], 64% of calves born from embryo transfer using embryos produced in vitro were male. In the future, changes in culture conditions should eliminate this problem. Indeed, sexed semen, which has now been developed and will one day become commercially available, is ideally suited for IVF since one straw of semen can be used to produce multiple embryos.

Embryo Transfer and Estrus Detection

Use of embryo transfer in the summer is made difficult by the fact that estrus detection is reduced during heat stress. It is inefficient to place embryos into recipient cows at 7 or 8 days after estrus when estrus is not observed in 50% or so of the cows. Fortunately, the same hormonal treatments that can be used to synchronize ovulation for AI can also be used to synchronize ovulation for embryo transfer. In our hands, we have transferred embryos into recipients in which ovulation was synchronized with the GnRH-PGF-GnRH scheme used for OvSynch (with or without prostaglandin presynchronization). Pregnancy rates achieved with timed embryo transfer are shown in Figure 4 and a typical timed embryo transfer scheme is detailed in Table 1.

Take Home Messages

Heat stress can be a difficult problem to manage. There are several things to keep in mind when trying to mitigate its effect on reproduction. These include the following:

- Keep cows as cool as possible by providing them with access to shade, forced air ventilation, and some form of evaporative cooling such as sprinklers or misters.

- Measure body temperatures in the afternoon in subsets of cows in each animal housing area to see how good of a job you are doing at keeping cows cool and work to improve the situation when body temperatures are often above 102.2°F.

- Use tail chalk, KaMars or other devices to facilitate detection of estrus in the summer.

- Consider the use of OvSynch in the summer to improve the number of cows submitted for insemination. OvSynch is more likely to pay for itself when the estrus detection rate is very low.

- Be careful before making the decision to use natural breeding in the summer and make sure that the bulls themselves won't be adversely affected by heat stress.

- Consider the use of embryo transfer as a reproductive management tool for getting cows pregnant during heat stress.

Acknowledgements

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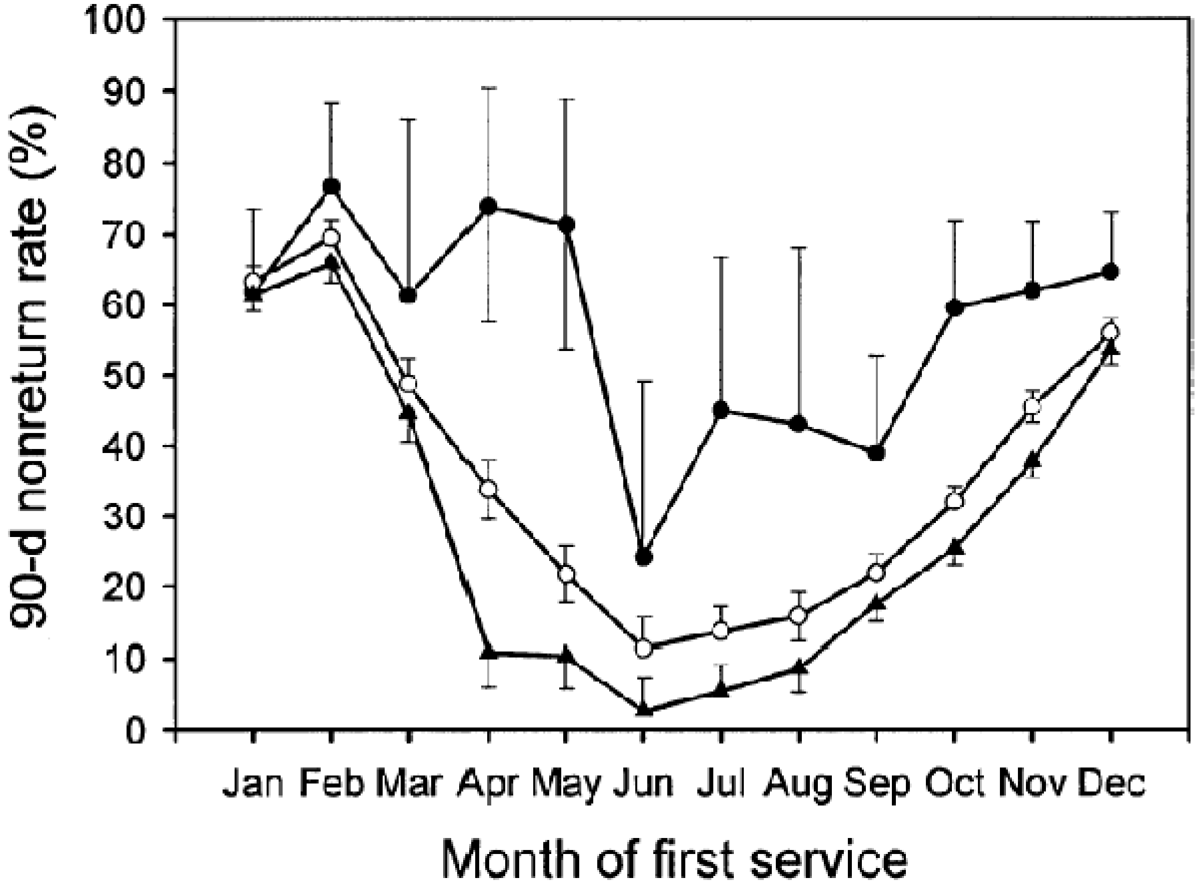

Figure 1. The effect of milk yield on seasonal variation in 90-day nonreturn rate in dairy cows in Florida and South Georgia. The term 90-day nonreturn rate signifies the percentage of cows that were not seen in estrus in the 90 days after insemination. The lines represent data for cows producing less than 10,000 lb of milk per lactation (closed circles), 10,000-20,000 lb (open circles), and greater than 20,000 lb (closed triangles). Data are from Al-Katanani et al., J. Dairy Sci. 82, 2611-2615 (1999).

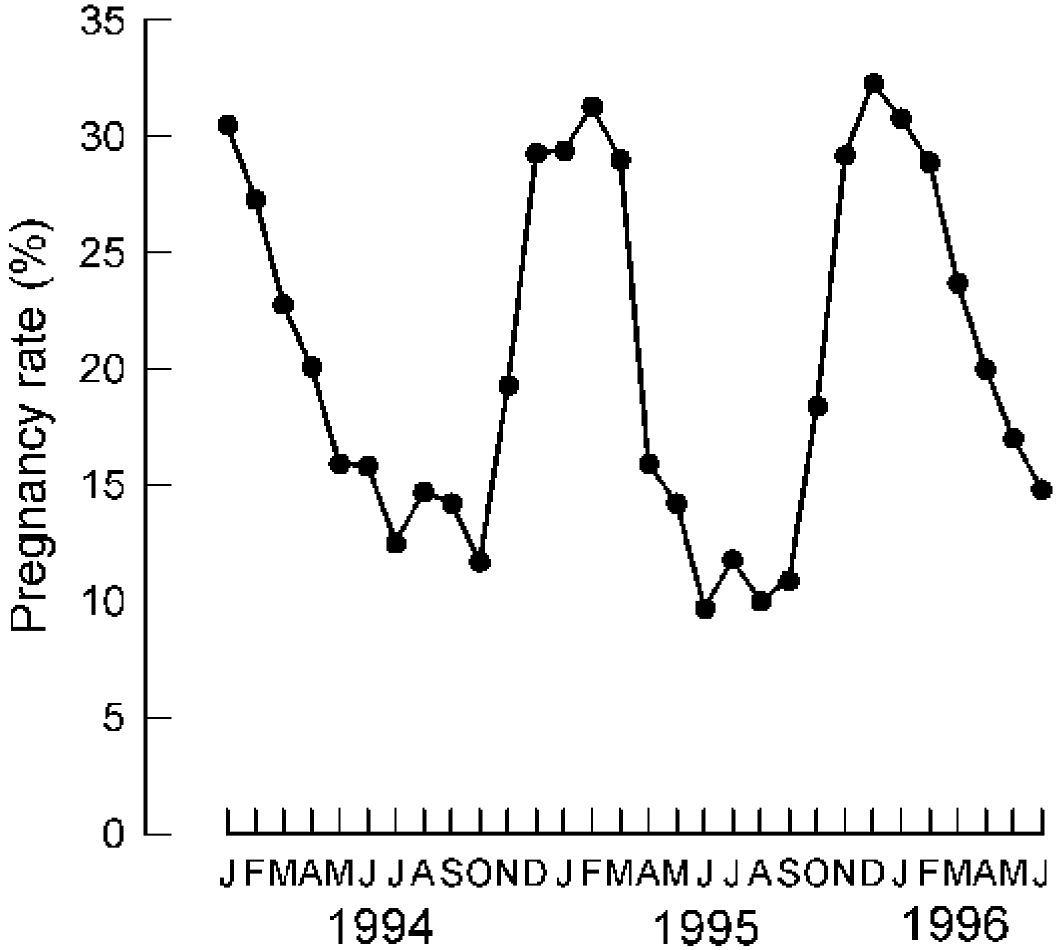

Figure 2. Seasonal variation in pregnancy rate (number pregnant/number inseminated) on a commercial dairy in Florida in which cows were housed in freestall barns with fans and sprinklers. Data are from Hansen and Aréchiga, J. Anim. Sci. 77 (Suppl 2): 36-50 (1999).

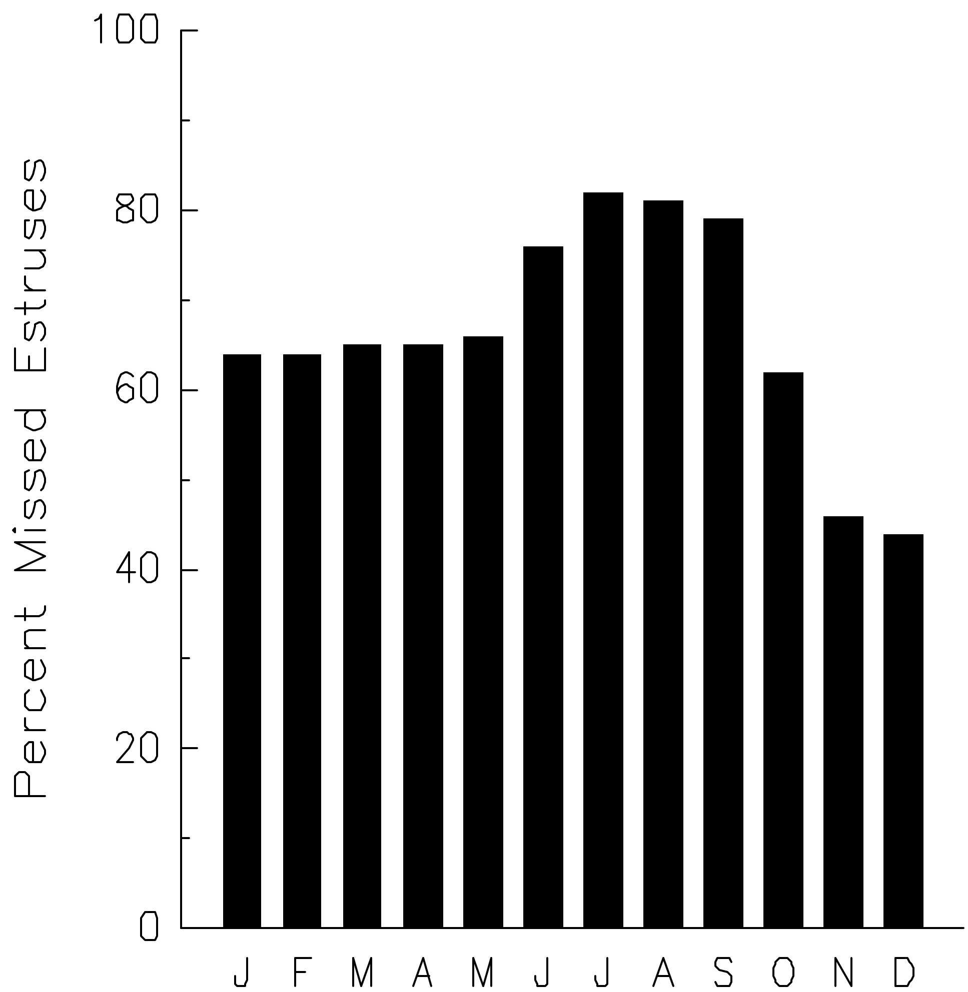

Figure 3. Seasonal variation in the estimated proportion of missed estruses in a Jersey herd in North Florida. Data come from Thatcher and Collier (In D.A. Morrow, ed., Current Therapy in Theriogenology 2, Philadelphia, WB Saunders, 1986).

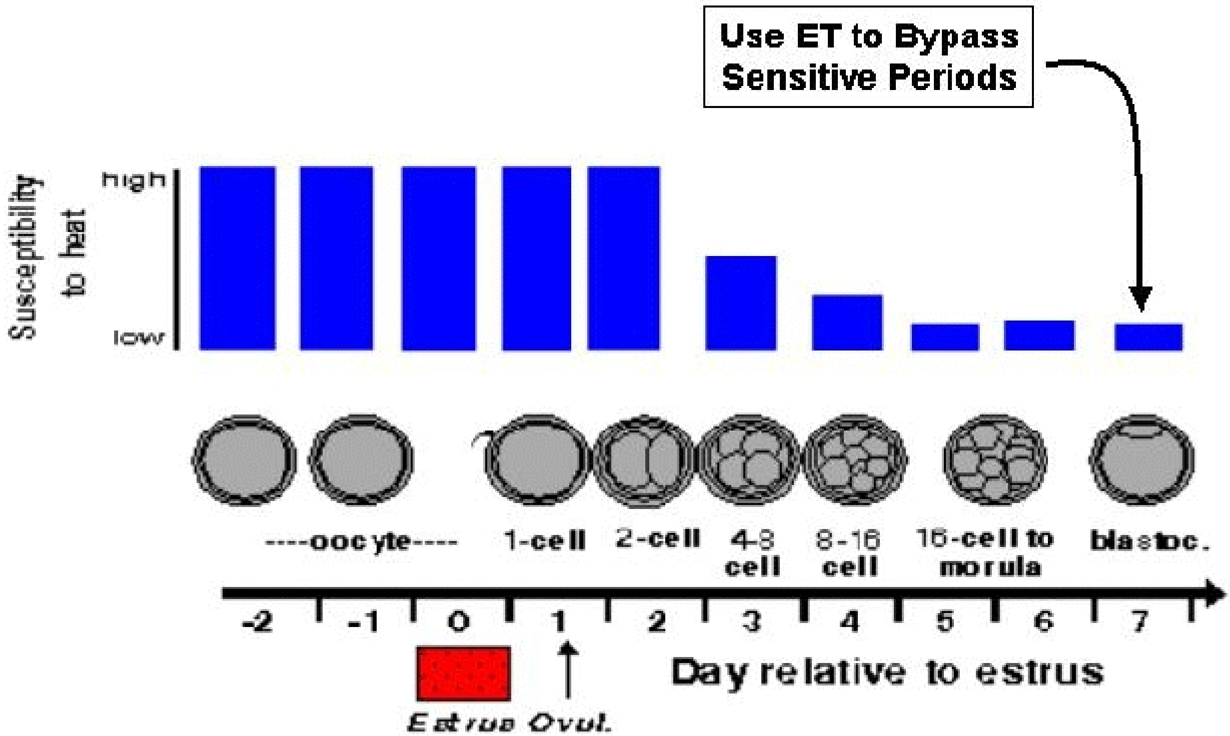

Figure 4. Illustration of the mechanism by which embryo transfer can be used to increased fertility in heat-stressed cows. Before estrus, the oocyte growing within the follicle is very sensitive to disruption by exposure of cows to heat stress. After estrus and ovulation, the oocyte and newly fertilized embryo is also very sensitive to elevated temperature. As the embryo grows, it becomes more resistant to heat stress. Transfer of an embryo into the uterus at day 7 after estrus thus bypasses effects of heat stress on the oocyte and early embryo.

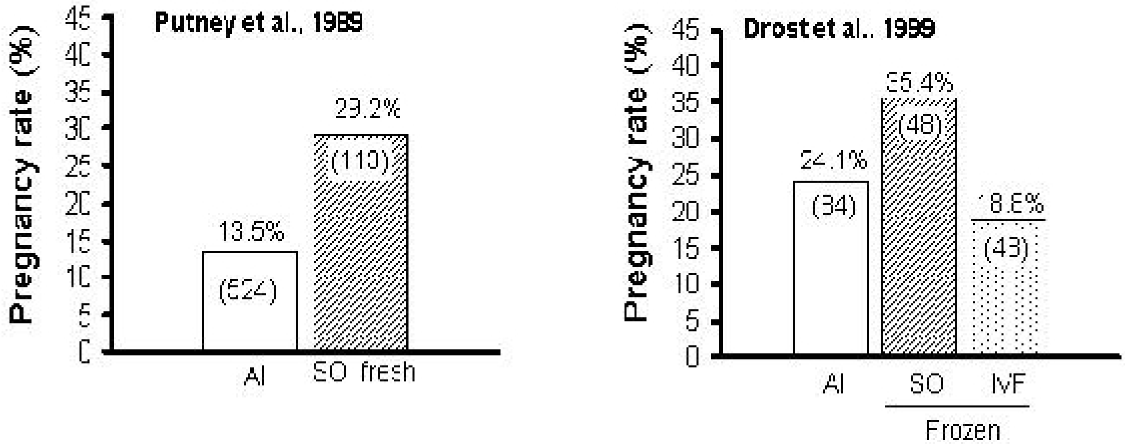

Figure 5. Effectiveness of embryo transfer for improving pregnancy rates of lactating dairy cows during heat stress. Experiments were conducted in Florida during the hot period of the year. Embryos were transferred after collection (fresh) or after cryopreservation (frozen). Pregnancy was determined by rectal palpation at 40-60 days of gestation. Abbreviations are AI=artificial insemination, SO=superovulation, and IVF=embryo produced by in vitro fertilization. Numbers above each bar represent percent pregnant and numbers in parentheses are the number of recipients. Data are from Putney et al. [Theriogenology 31, 765-778 (1989)] and Drost et al. [Theriogenology 52,1161-1167 (1999)].

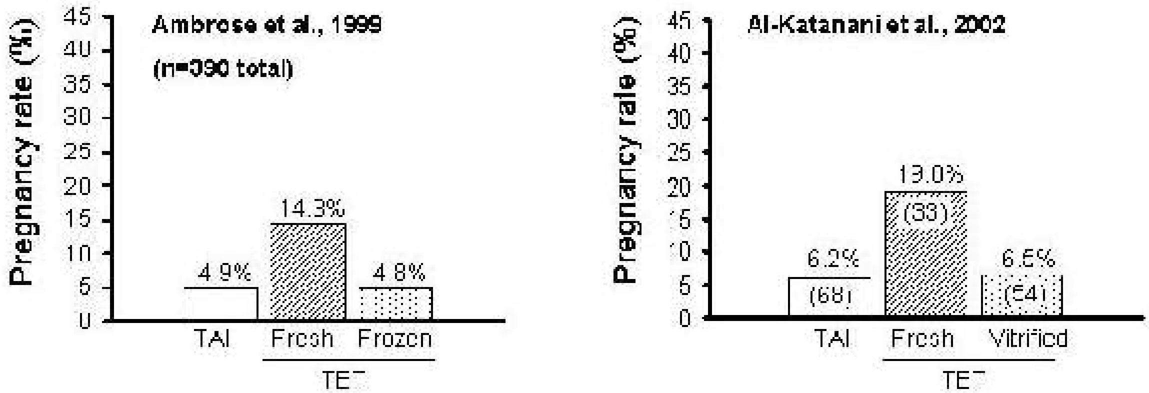

Figure 6. Effectiveness of timed embryo transfer using embryos produced in vitro for improving pregnancy rates of lactating dairy cows during heat stress. Experiments were conducted in Florida during the hot period of the year. Ovulation was synchronized using the OvSynch procedure and cows were either inseminated at a fixed time (timed AI; TAI) or received an embryo at a fixed time (timed embryo transfer; TET). Embryos were either unfrozen (fresh), or were frozen by conventional procedures (frozen) or by vitrification (vitrified). Pregnancy was determined by rectal palpation at 40-60 days of gestation. Numbers above each bar represent percent pregnant and numbers in parentheses are the number of recipients. Data are from Ambrose et al. [J. Dairy Sci. 82, 2369-2376 (1999)] and Al-Katanani et al. [Theriogenology 58, 171-182 (2002)].