REPRODUCTIVE LOSS IN FARM ANIMALS DURING HEAT STRESS

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1. INTRODUCTION

Heat stress causes infertility in farm animals and represents a major source of economic loss. In response to heat stress, managers can attempt a variety of approaches to improve reproduction. These approaches usually involve modifying the environment (i.e., attempting to cool cows during reproduction), modifying the genetics of the animal (i.e., breeding to heat tolerant breeds) or intensifying reproductive management during periods of heat stress. Heat stress affects reproduction in all major farm species. Dairy cattle are particularly sensitive to heat stress because of the metabolic heat produced in lactating cows. This review will focus specifically on the effects of heat stress on reproduction in dairy cows. The reader is referred to additional reviews on heat stress and reproduction in sheep (Silanikove, 2000), pigs (Wettemann and Bazer, 1985), and poultry (Daghir and Jones, 1995).

2. GENERAL EFFECTS OF HEAT STRESS ON REPRODUCTION

Conception rates for dairy cows in the United States typically decrease 10 to 20% in summer (Figure 1). Heat stress causes infertility throughout the United States but is most important in subtropical and desert regions. The loss of conception has led some dairymen to suspend breeding in the summer in large United States dairy herds. Lactating dairy cows are particularly sensitive to heat stress because they have high metabolic heat production associated with milk production. Furthermore, high producing dairy cows are most susceptible to heat stress. In a recent study of Florida dairy cows, al-Katanani et al. (1999) examined 90-day return rates throughout the calendar year and found that summer infertility was greatest in the highest milk producing dairy cattle. Therefore, there is an additive effect of heat stress and greater milk production for decreasing conception rate in dairy cattle.

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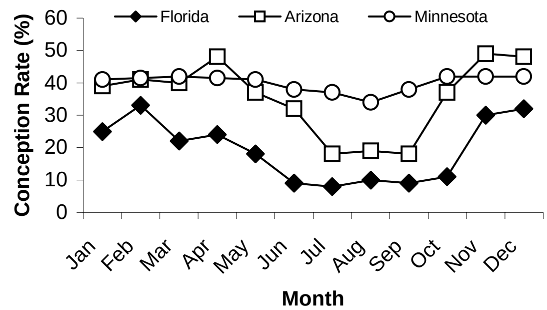

Figure 1. Conception rates for United States dairy cows in Florida (sub-tropical climate), Arizona (desert southwest) and Minnesota (temperate climate). Adapted from Hansen, 1997.

The effects of heat stress can be directly related to the increase in body temperature in heat-stressed cows. Ulberg and Burfening (1967) showed that small increases in maternal body temperature would cause decreased pregnancy rates in cattle (Figure 2). The increase in body temperature affects the reproductive tract and the early embryo. These changes in the reproductive tract influence the ability of a cow to become pregnant during heat stress.

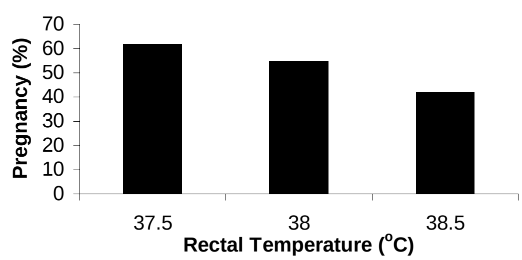

Figure 2. Pregnancy rates for cattle with different rectal temperatures at the time of breeding (Ulberg and Burfening, 1967).

3. HEAT STRESS AND THE OVARY

The ovary houses ovarian follicles and corpora lutea, each of which influences the ability of the cow to become pregnant.

3.1 Oocyte and Ovarian Follicles

Ovarian follicles contain gametes (oocytes) as well as somatic cells that synthesize estradiol. Estradiol has a variety of actions that include causing estrus and the luteinizing hormone (LH) surge. Oocytes that reside in the ovary are clearly influenced by heat stress. The negative effects of heat stress on oocytes are manifested in the summer as well as in the fall, after ambient temperatures have decreased (Figure 1). Therefore, follicles that are developing on the ovary in heat-stressed cows can be damaged but nevertheless continue growing. Apparently, these damaged follicles ovulate sub-fertile oocytes during the summer and fall.

The somatic cells within the follicles (theca and granulosa cells) can also be damaged by heat stress. We found that follicles did not grow normally and had low estradiol production in cows and heifers subjected to heat stress (Wilson et al., 1998ab). Others have studied heat stress and found similar effects on ovarian follicles (Badinga et al., 1993). Therefore, heat stress damages ovarian follicles and causes a decrease in estradiol synthesis. This decrease in estradiol synthesis could influence expression of estrus, ovulation, and the corpus luteum.

3.2 Corpus luteum

In addition to influencing the ovarian follicles, heat stress can affect the corpus luteum. Progesterone from the corpus luteum is required for pregnancy and there is an association between low progesterone and infertility. We noted that cows subjected to heat stress had longer luteal phases (Wilson et al., 1998ab). Estradiol from the follicle initiates luteolysis in cattle. Therefore, we hypothesized that the decrease in follicular estradiol caused by heat stress (see above) prevented the normal luteolyic process in cattle. Cows had luteolysis after the heat stress was removed and follicles resumed normal development.

Whether or not heat stress affects the corpus luteum during the mid-luteal phase is less clear. Heat stress has been shown to increase, decrease or have no effect on blood concentrations of progesterone (Hansen and Aréchiga, 1999). The cells of the corpus luteum differentiate from the cells of the follicle. Therefore, if heat stress decreases blood progesterone then the decrease could arise from the effects of heat stress on the follicle which ultimately carries over to the corpus luteum. Alternatively, changes in metabolic rate associated with heat stress may alter the metabolism of progesterone.

4. HEAT STRESS AND ESTRUS

Cows must be observed in estrus so they can be inseminated artificially. There is clear evidence that heat stress decreases the length and intensity of estrus. For example, Nebel et al. (1997) demonstrated that dairy cows in the summer had approximately one-half the number of mounts per estrus compared to dairy cows in the winter. Thatcher and Collier (1986) demonstrated a similar change in Florida dairy cows. The intensity of estrous expression is increased when heat-stressed cows are cooled. Heat stress decreased follicular estradiol in some studies (Wilson et al., 1998ab). Therefore, the decrease in estrous intensity may be caused by a decrease in follicular estradiol secretion. Although this is an attractive hypothesis, the blood estradiol concentrations needed to trigger behavioral estrus are poorly defined. Thus, it is impossible to say whether or not heat-stressed dairy cows fail to reach a minimum threshold of estradiol for expression of estrus. An equally likely cause of reduced estrous expression is the physical inactivity caused by heat stress. Cows are less active during heat stress and therefore less likely to ride other cows during estrus.

5. HEAT STRESS AND THE EMBRYO

There are effects of heat stress on the ovary and these effects may influence the ability of cows to become pregnant. However, the direct effects of heat stress on the embryo are much greater. The period of greatest susceptibility is immediately after the onset of estrus and early during the post-breeding period. Putney et al. (1989b) demonstrated that embryonic development was impaired in heifers subjected to heat stress for 10 hours after the onset of estrus. This is an interesting period of development because it represents a time after the LH surge but before ovulation. Ealy et al. (1993) found that heat stress on day 1 after breeding also decreased subsequent embryonic development (Figure 3). Heat stress on days 3, 5, or 7 after breeding, however, did not affect embryonic development. Therefore, the period of embryonic sensitivity to heat stress begins early during the development of the follicle (suggested by the carry-over effects of heat stress on pregnancy in cattle, see above) and continues until about 1 day after breeding. By 3 days after breeding, embryos have apparently developed resistance to the effects of heat stress.

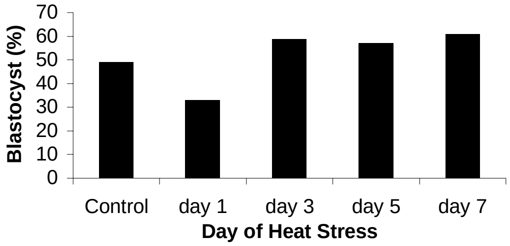

Figure 3. Effect of heat stress on percentage blastocysts recovered on day 8. Cows were heat-stressed on day 1, 3, 5, or 7 after estrus (day 0) or were non-heat-stressed control (Ealy et al., 1993).

6. METHODS TO INCREASE CONCEPTION IN HEAT-STRESSED COWS

6.1 Improving Rates of Estrous Detection

Some of the effects of heat stress are caused by reduced intensity of estrous expression. Therefore, it may be possible to improve reproduction in dairy herds by improving estrous detection methods. Ealy et al. (1994) demonstrated that using tail chalk could improve estrous detection rates in Florida dairy cows during the summer. Other estrous detection aids including pressure activated patches or electronic devices placed on the tail head should theoretically improve reproductive performance of dairy cows during heat stress.

6.2 Timed Artificial Insemination (Timed AI)

If estrous detection is a problem in heat-stressed dairy cows then it may be possible to improve reproduction by using timed AI. Timed AI is done by administering a series of gonadotropin releasing hormone (GnRH) and prostaglandin F_{2_α} (PGF) injections. Insemination is performed at a predetermined time following the last GnRH injection. Timed AI shortened the interval to first service and increased pregnancy rates in heat-stressed cows when compared to insemination at observed estrus (Aréchiga et al., 1998; de la Sota et al., 1998). Therefore, timed AI is a good alternative when attempting to reproductively manage cows during heat stress.

6.3 Cooling

Infertility during heat stress is primarily caused by elevated body temperature within the dairy cow. Cooling dairy cows during heat stress should, therefore, improve conception rates. A variety of cooling systems are available for heat-stressed dairy cows. Perhaps the most widely used system is a combination of water sprinklers and fans. Sprinkling cows with water and subsequently blowing air over the cow with a fan causes evaporative cooling. The evaporative cooling decreases body temperature. Several investigators have tested the effects of cooling on reproduction. In general cooling cows will improve reproductive performance. However, cows cooled in the summer never achieve the same rates of conception when compared to normal cows in the winter. Therefore, cooling can only partially alleviate the effects of heat stress on reproduction.

6.4 Embryo Transfer

Embryos are sensitive to the effects of heat stress. However, greatest sensitivity occurs early during embryonic development. Later during embryonic development (morula or blastocyst stage), embryos develop some tolerance for heat stress. It should be possible, therefore to improve pregnancy rates in heat-stressed cattle by using embryo transfer of frozen embryos collected from cows that are not heat stressed. Several investigators at the University of Florida have used this approach (Putney et al., 1989a; Ambrose et al., 1999; Drost et al., 1999). Embryo transfer nearly doubled conception rates when compared to Florida dairy cows inseminated artificially. Therefore, it is possible to by-pass early embryonic stages and improve conception rates during heat stress. The practicality of this approach is only limited by the availability of good quality embryos at an affordable price.

7. CONCLUSIONS

Heat stress decreases fertility in dairy cows. The decrease in fertility is caused by elevated body temperature that influences ovarian function, estrous expression, oocyte health, and embryonic development. In response to these limitations, dairymen should increase environmental and reproductive management of cows during heat stress. For example cooling dairy cows and increasing the frequency of estrous detection will improve pregnancy rates. Timed AI may also be used as an alternative to estrous detection. Future strategies for managing heat stress may involve embryo transfer if sources of affordable high-quality embryos become available.

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