STRATEGIES FOR IMPROVING THE REPRODUCTIVE FUNCTION OF DAIRY CATTLE IN SUBTROPICAL CLIMATES

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ABSTRACT

The pregnancy rates of lactating dairy cows are depressed during summer in hot climates. Over the last two decades, some new approaches have become available for overcoming the reduced expression of estrus in cows suffering from heat stress. Several estrus-detection aids are available. These include Heat Watch® transponders, Kamar® detectors and tail paint. Providing sprinklers and a forced ventilation cooling system is beneficial in decreasing the rectal temperature and improving the pregnancy rate. GnRH treatment enhanced the secretion of luteal progesterone and embryo survival. The Ovsynch protocol proved to be a useful tool to synchronize ovulation in cows, and improve the fertility at fixed-time postpartum in summer. Periovulatory oocytes and early embryos appear to be highly susceptible to heat stress. Heat stress had more effect on embryonic development and viability when it occurred on the day of estrus or the day after, than if it occurred within three days after estrus. The transfer of embryos to recipients on day 7 after estrus avoided the deleterious effects of heat stress. However, there is clearly a delayed effect of summer heat stress on oocyte quality in the autumn. Enhanced removal of impaired follicles from previously heat-stressed cows produced a improvement in the quality of oocytes collected in the autumn. This in turn led to the earlier emergence of healthy follicles and better quality oocytes. In terms of antioxidants, long-term feeding of ß-carotene increased the herd pregnancy rate of cows. However, the feeding of vitamin E had no beneficial effects on pregnancy rates at times of heat stress.

INTRODUCTION

The most comfortable and productive environmental temperature range for dairy cows is between -5°C and 25°C (McDowell 1972). This is the thermal comfort zone. When environmental temperatures exceed 26°C, milk production declines. This is mainly because of a decrease in the dry matter intake (DMI). Reduced DMI is an adaptation strategy to maintain a normal body temperature (i.e. in the range 38.5 - 39.3°C). Reproductive performance is also affected negatively by summer heat stress.

Summer heat stress is a major factor contributing to low fertility in lactating dairy cows. Conception rates drop from about 40-60% in cooler seasons to 10-20% in warm seasons (Cavestany *et al*. 1985). The substantial rise in average milk yields in recent years has aggravated the low summer fertility syndrome, because of the concurrent rise in metabolic heat production. Every dairy cow has a natural body heat balance which is optimal for normal physiological processes and productive functions. A normal body heat balance exists only when the net heat gain equals the net heat loss.

In Taiwan, low fertility is associated mainly with the warm season (June to September). However, fertility is lower in October and November than in December in Taiwan (Fung and Shiea 1981). Recent research indicated that this is because of the delayed effect of summer heat stress on autumn fertility (Roth *et al.* 1997).

In the past decade, fans and sprinkling evaporative cooling systems have come into widespread use for lactating dairy cows (Bucklin *et al.* 1988). Studies of this type of cooling system have also been conducted in Taiwan (Lee *et al.* 1999). The first part of this

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paper focuses mainly on the adverse impact of heat stress on embryonic development and cow fertility. The second part discusses the practical management of dairy cattle, and the use of hormones to improve reproductive performance.

ASPECTS OF IMPAIRED REPRODUCTION

Heat detection

It is more difficult for bulls to detect estrus in cows which are suffering from heat stress. Neble *et al.* (1997) demonstrated that the number of mounting episodes per estrus for Holstein cows was only 4.5 in summer, compared to 8.6 in winter.

Oocyte competence

Research in Louisiana (Rocha *et al.* 1998) showed that the effect of the season on the production of embryos via *in vitro* maturation, fertilization and development in Holstein cattle was different than in Braham cattle. In this study, the proportion of oocytes classified as morphologically normal, and the rate of blastocyst development following *in vitro* fertilization, was lower in summer than in winter.

Damage to spermatozoa

The exposure of spermatozoa to elevated temperatures in the uterus or oviduct of a female suffering from heat stress could compromise sperm survival in the uterus and fertilization (Monterroso *et al.* 1995).

Embryonic development

Early development of the embryo can be compromised by heat stress. It is documented that embryos recovered from superovulated cows in Arizona, USA, from June to September were less able to develop in culture than similar embryos collected from superovulated cows from October to May (Monty and Racowsky 1987).

Delayed effects

Roth *et al.* (2000) showed that exposing cows to thermal stress during one estrous cycle altered follicular dynamics and attenuated follicular dominance in the subsequent cycle. Thus, exposure of follicles to high temperatures in the summer, during the early stages of development, may impair oocyte quality and subsequent embryo development in autumn. A period of about two months is needed for low autumn fertility to be restored to the level prevailing in winter.

Protein and prostaglandin synthesis

The effect of *in vitro* heat stress on the synthesis and secretion of protein and prostaglandin by bovine conceptuses and endometrium was examined (Putney *et al.* 1988). An elevation in the temperature of tissue incubation from 39°C to 43°C induced a larger reduction in conceptus protein synthesis and secretion, and stimulated the release of PGF by the endometrium of pregnant cows. These *in vitro* results suggest that the exposure of pregnant cows to high temperatures and humidity may disrupt the balance between conceptus and endometrial biochemical factors responsible for maintaining the pregnancy.

STRATEGIES FOR IMPROVING REPRODUCTIVE PERFORMANCE

Use of aids to estrus detection

Several estrus-detection aids are available, including Kamar® detectors, Heat Watch® transponders and tail paint. Not much research has been conducted to determine how effective any of these are under conditions of heat stress. Ealy *et al.* (1994) reported that the use of tail chalk increased the proportion of cows detected in estrus within 96 hours, following injection of $PGF_{2\alpha}$ from 24% to 43%.

Combination of sprinkling and forced ventilation

A method of cooling dairy cattle has been examined, based on wetting them repeatedly to trap the maximum amount of water in the coat, followed by its rapid evaporation using forced ventilation (Flamenbaum *et al.* 1986). When cows were cooled five times a day for 30 minutes, they remained at a temperature of 38.2 - 38.9°C during the day. This was significantly lower than for those not cooled.

This simple system is a combination of short-duration (0.5 to 3 minutes) sprinkling with water from overhead sprinklers, followed by forced ventilation with electric fans lasting 4 to 15 minutes until the cows are almost dry. An automatic device can be installed so that sprinkling and ventilation are alternated continuously while cows are in holding areas (360^o pattern) or a feeding area (180^o pattern).

A similar experiment was conducted in Taiwan (Lee *et al.* 1999). Cooling was carried out by an automated system, which alternated sprinkling (1 minute) followed by forced ventilation (5 minutes) for 30 minute periods. Cows were cooled 7-9 times each day, beginning at 6 AM up until 10 PM, over 4 months (from June through September). On average, rectal temperatures fell by 0.2^{o}C after cooling, thus maintaining the cows in the range of 38.7 - 39.2^{o}C. Fans should be tilted about 30 degrees from the vertical, so that they blow down to the floor directly under the next fan.

Use of embryo transfer technologies

Putney *et al.* (1989) obtained embryos from superovulated Holstein heifers. When these were transferred to synchronized lactating cows, a pregnancy rate was achieved of 29.2%. The pregnancy rate for AI contemporary controls was 13.5%.

In an attempt to obtain better quality embryos, Rutledge (1999) reported seasonally related differences in oocyte quality in Wisconsin as judged from an *in vitro* embryo production system.

Finally, lowered pregnancy rates may result from reduced ability of the dam to support a competent embryo. Drost *et al.* (1999) compared conception rates after the transfer of frozen-thawed embryos derived *in vivo* or *in vitro* relative to those following AI during summer heat stress in lactating cows. Conception rates at day 42 differed (AI, 21.4%; ET, 35.4%). Rutledge (2000) reviewed the literature and showed that higher pregnancy rates can be obtained from the transfer of cleavage stage embryos. The aim of this study was to use embryo transfer and IVF to bypass the effects of heat stress. It seems such techniques may help solve this long-standing problem.

Use of exogenous hormones

Injecting cows with GnRH causes a predictable release of LH and a significant increase in serum progesterone. In one study, Ullah *et al.* (1996) indicated that if cows were injected with 100 ug of GnRH when estrus was first detected, followed by AI ten or twelve hours later, the pregnancy rate from the first AI was 28.6% for all treated cows. This can be compared to 17.7% in the control cows.

A more recent approach is to use a timed insemination program, based on breeding the cows at a fixed time. This Ovsynch protocol (GnRH at day 0, $PGF_{2\alpha}$ at day 9 and insemination 16-24 hours later) increased the pregnancy rate at fixed times postpartum (de la Sota *et al.* 1998).

The same ovulation synchronization protocol has also been used by Lee (1999) in Taiwan. The pregnancy rate of lactating cows in summer, when cows were first serviced postpartum using Ovsynch, was 25.0%. This can be compared to the 15% pregnancy rate when cows were first serviced when estrus was detected. The results suggest that timed AI using the Ovsynch protocol in mid-lactation is an effective and economic way of managing the reproduction of lactating cows in a subtropical environment.

Improving the quality of oocytes

The fertility of dairy cows falls during the summer. It remains low during the autumn, even though the cows are no longer subjected to heat stress. Roth *et al.* (2001) described this delayed effect of summer heat stress on oocyte quality in the autumn. They suggested that oocyte quality could be improved by enhanced removal of follicles damaged during the previous summer. In autumn, follicles (3-7 mm in diameter) were aspirated from the ovaries by an ultrasound-guide procedure during four consecutive estrous cycles. This led to the earlier emergence of healthy follicles, and high-quality oocytes in the autumn.

Use of antioxidants

Heat stress was associated with reduced activity by antioxidants in the blood plasma (Harmon *et al.* 1999). The treatment of cows with antioxidants to improve fertility in summer has given inconsistent results. Long-term feeding (>90 days) of supplemental ß-carotene increased the herd pregnancy rate for cows in Florida. The number of cows pregnant by day 120 postpartum was 21% in the control and 35% for cows fed supplemental ß-carotene (Arechiga *et al.* 1998). However, Ealy *et al.* (1994) found that feeding vitamin E to cows had no consistent beneficial effect on their pregnancy rates during either summer or winter.

CONCLUSION

A very effective environmental management system to control heat stress can be planned and implemented by integrating two ideas:

- Protect the cows from the factors contributing to heat-stress; *and*,
- Enhance evaporative heat loss.

The major objective with a cooling system is to keep the cow's body temperatures as close as possible to normal (38.5 - 39.3°C).

Evaporative cooling can be accomplished in two ways.

- Direct evaporation from the skin of the cows; *and*,
- Indirect evaporation with cooling pads and fans in an enclosed barn, to modify the microenvironment of the cows.

In hot, humid environments, effective evaporative cooling always requires use of forced ventilation. Sprinklers without fans, or fans without sprinklers, will not result in an effective evaporative cooling system in a hot humid environment.

It has been difficult to modify the effect of warm weather on fertility. Therefore, any embryo production program should be carried out during cool seasons. Use of estrus detection aids such as Kamar® detectors and Heat Watch® transponders or tail paint can reduce heat detection problems. Both in theory and in practice, higher pregnancy rates can be obtained by the transfer of late cleavage stage embryos. This demonstrates that embryo transfer can bypass the effect of heat stress on subsequent embryo development.

Studies on the delayed effect of heat stress show that cows need to be cooled as efficiently as possible over the whole summer in order to raise summer fertility. Currently, summer fertility in subtropical Asia remains low.

The use of hormone treatments to improve pregnancy rates is still limited. The use of timed-AI procedure or ovulation synchronization protocol improves pregnancy rates. In the long term, pharmacological approaches may be developed that involve the use of embryotrophic drugs or antioxidants, to overcome the damaging effects of overheating caused by heat stress.

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