Impact of Heat Stress on Production and Fertility of Dairy Cattle

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Abstract

Summer heat stress depresses both milk production and reproductive performance of dairy cows. The use of efficient cooling systems is required because high milk-producing cows are not capable of maintaining normothermia in the summer. Cooling, if efficient enough, is capable of narrowing the gap between winter and summer milk production; however, its positive effect on fertility is limited. Fertility surveys show that, unlike milk yield, the improvement of conception rate by cooling is small. Therefore, additional hormonal treatments are required. Various hormonal approaches have been examined: addition of exogenous progesterone, injection of gonadotrophin releasing hormone **(GnRH)** at onset of estrus, the timed artificial insemination **(AI)** (Ovsynch) protocol, embryo transfer, and induction of follicular waves by GnRH and prostaglandin $F_{2á}$ **($PGF_{2á}$)**; their potential for improving summer fertility is presented.

Introduction

Heat stress is a worldwide problem. About two thirds of the world's cattle population is located in hot zones. Summer heat stress is a major factor contributing to low milk production and low fertility in lactating dairy cows. The problem is multifactorial in nature, because various tissues are being affected and their function is disrupted under heat stress conditions (Wolfenson et al., 2000). High milk production is associated with high metabolic heat production. As a result, cows have to dissipate large amounts of heat in order to maintain normothermia. At air temperatures around 27ºC (80°F), under humid climates, the body temperature of lactating cows rises above normothermic values, and severe hyperthermia develops as air temperature rises above 86 to 90ºF and above. In several middle-eastern states in the USA, the ambient temperatures rise to values that induce hyperthermia in lactating cows during the summer.

During the 1980's we developed in Israel an efficient cooling system that is based on direct cooling by evaporation of water from the skin (Flamenbaum et al., 1986). Since the sweating rate in cattle is relatively low, it became necessary to wet the skin and saturate the coats of cattle with water. Short-term water sprinkling followed by ventilation facilitates water evaporation and the rate of cooling. The sprinkling (or misting) and ventilation cooling system is widely used in several hot countries, including southern states in the USA (Berman and Wolfenson, 1992).

Effect of Cooling on Milk Yield and Fertility

The effect of cooling on milk production and reproductive performance differs substantially, in the sense that summer cooling is capable of markedly improving summer milk yield, whereas summer fertility is only slightly improved. The following large survey, conducted in Israel over a 4-year period, is a typical example illustrating the

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effect of summer cooling on milk production and reproductive performance (Flamenbaum and Ezra, 2003). Farms were classified into 3 different groups according to the intensity of cooling in summer. Farms that used intensive cooling, cooled cows in both the holding and feeding areas for a total of 10 cooling periods and 7.5 cumulative hours per day. Each cooling period combined cycles of sprinkling (30 seconds) and ventilation (4.5 minutes). Farms that used moderate cooling, cooled cows in the holding area only for a total of 6 cooling periods and 4.5 cumulative hours per day. Farms that used minimal cooling, cooled cows 3 times before milking in the holding area. Milk production for summer and winter included 125,000 milk records and 17,000 inseminations. The average high temperature in summer was 31.8°C (89°F). The ratios between summer and winter milk production for multiparous cows in farms using intensive, moderate, or minimal cooling regimes were 98.5%, 96.1%, and 90.7%, respectively. Conception rates for multiparous cows were 46.6%, 45.8%, and 43.5% in winter, and 33.8%, 34.5%, and 16.7% in summer for farms using intensive, moderate, or minimal cooling regimes, respectively. The results clearly show that intensive cooling is capable of minimizing, but not completely eliminating, the drop of milk yield in summer, compared with that in winter. Improvement of milk yield by cooling is due, partly, to an increase of food intake. Lower food intake during heat stress is known to be a major cause of low milk production during the summer. However, studies show a direct disruptive effect of heat stress on milk synthesis and on alterations in the secretion of hormones and metabolites involved in milk production, which are not related to low food intake. In contrast to milk yield, the slightly improved conception rates by cooling still remained much lower in summer than in winter.

Low fertility in summer was recorded in several US states. Conception rates drop from about 30% in winter to about 12% in the humid summer in Florida. In the dry climate of Arizona, conception rates drop from about 40% to around 20%. In the Midwest, summer conception drops as well. For example, conception rates of about 12,000 cows in three farms in Missouri dropped from 30.2% in the winter to 21% in the summer and 24.5% in the cool months of the fall (S. Poock, College of Veterinary Medicine, University of Missouri, personal communication, 2008).

The main conclusion of the above are as follows: (1) Improving milk production can be accomplished by means of efficient cooling, and that summer milk yield may reach a production level that is lower by only 2 to 4% of that in the winter, and (2) in contrast, fertility in summer cannot approach winter conception rates. This is because several components of the reproductive system are susceptible to thermal stress, and disruption of any single one may terminate pregnancy. Therefore, an efficient cooling system is a prerequisite for improving summer fertility; however, additional hormonal treatments are required in order to improve summer fertility of dairy cows.

Hormonal Strategies Aimed at Improving Summer Fertility

Evaporative cooling improves summer fertility to some extent; however, there is a compelling need to find additional ways to further improve fertility during the hot season. Five approaches to improve summer fertility of lactating cows are presented below. In all, efficient cooling is required to lower body temperature as much as possible to a level that enables embryonic survival.

First approach: exogenous progesterone

Dairy cows during the summer exhibited low concentrations of plasma progesterone. Supplementing exogenous progesterone post AI in summer was equivocal in term of its effect on conception. The variability among studies in thermal stress severity, and whether or not efficient cooling was applied, contributed to the variable effect of exogenous progesterone on summer fertility. We examined the effect of supplementing exogenous progesterone post-AI on conception rates during the summer and autumn for lactating cows that were efficiently cooled during the hot season (Wolfenson et al., 2009). Treated cows received an intravaginal device containing progesterone (Controlled Intravaginal Drug Release; **CIDR**) on day 5 after AI for 12 days. A total of 377 cows were included in the study. The CIDR increased progesterone concentrations by about 2 ng/ml. Overall, CIDR treatment increased (not significantly) conception rates by 6% compared with controls (33 vs. 39%). However, the CIDR treatment significantly increased (+23%, $P < 0.05$) the conception rates of cows with low body condition scores at peak lactation. Similarly, CIDR significantly increased (+22%, $P < 0.05$) the conception rate of cows that exhibited uterine disorder at parturition. The CIDR treatment increased numerically, but not statistically significant, the conception rate in the fall (+13%) and less so in the summer, and in mature cows (+8%) and less so in first-calf heifers. Results indicated that exogenous progesterone post AI increased the conception of cows that were efficiently cooled during the hot summer. The most beneficial effect of CIDR was documented in cows diagnosed as having uterine disease postpartum and in cows exhibiting low body condition score at peak lactation.

Second approach: GnRH at onset of estrus

The concentration of the preovulatory luteinizing hormone **(LH)** surge in the summer is lower than that in the winter. It has been shown that low LH surge can be associated with delayed ovulation, and with the formation of a suboptimal corpus luteum and the secretion of low progesterone levels (Bloch et al., 2006). A study was carried out during the summer and winter on 363 primiparous and multiparous cows (Kaim et al., 2003). Cows were synchronized and watched continuously for manifestation of estrus. A single dose of GnRH analogue was injected right after onset of estrus. In the summer, but not in the winter, GnRH treatment increased conception rates from 35.1 to 51.6%. In both seasons, GnRH increased the conception rates of cows with a low body condition score at AI and that of primiparous cows more than that of multiparous cows. It can be concluded that GnRH administered at estrus onset increases the preovulatory LH surge, prevents possible delays in ovulation, and is likely to increase the post-ovulation progesterone concentration. The GnRH administered at estrus onset was found more effective in primiparous cows and during the summer in increasing conception rate in cows with low body condition scores at AI.

Third approach: Timed AI

During the summer, the intensity and duration of estrous behavior are lower than that in the winter. As a result, the percentage of inseminated cows is lower in the summer. A possible treatment is to use the Ovsynch protocol for summer breeding. A study conducted in Florida (de la Sota et al., 1998) showed that the overall pregnancy rate by 120 days postpartum was higher for treated cows than for untreated control cows (27.0 vs. 16.5; $P < 0.05$). The number of days open for cows conceiving by 120 days postpartum was less for time-inseminated, Ovsynch-treated cows (77.6 ± 3.8 vs. 90.0 ± 4.2 days; $P < 0.05$), as was the interval to first service (58.7 ± 2.1 vs. 91.0 ± 1.9 days; $P < 0.01$). The authors concluded that the timed program did improve group reproductive performance. The timed program will not protect the embryo from temperature-induced embryonic mortality, but management limitations induced by heat stress on estrus detection are eliminated.

Fourth approach: Embryo transfer

It has been shown that the embryo at the very early stages of its development, during days 1 to 3 of pregnancy, is highly susceptible to hyperthermia, and that later during days 5 to 8 of pregnancy the embryo becomes more resistant to high temperatures. Therefore, performing embryo transfer of high-quality embryos on days 7 to 8 after estrus may improve conception rates. A study in Florida (Hansen and Aréchiga, 1999) showed that transfer of fresh embryos markedly improved pregnancy rates, whereas use of frozen embryos that had been thawed did not improve pregnancy rates above those obtained by using AI.

Fifth approach: induction of follicular waves

We showed in previous studies that the ovarian follicles and the enclosed oocytes are susceptible to thermal stress (Roth et al., 2001). We examined the possibility that induction of consecutive follicular waves by administration of GnRH + $PGF_{2á}$ with the aim to enhance the removal of damaged follicles and to enhance the emergence of healthier ones will improve fertility (Roth et al., 2009). Three consecutive 9-day follicular cycles were induced with GnRH and $PGF_{2á}$ 7 days later. Control cows were untreated. Cows were AI at estrus. Overall, the GnRH-$PGF_{2á}$ treatment resulted in a slight non-significant increase in conception rates compared with controls (27 and 32%). The treatment significantly increased conception rates of first-calf heifers (37 vs. 53%, $P < 0.05$), but not those of multiparous cows. The treatment increased numerically, but not statistically significant, compared with untreated controls the conception rates in cows with a milk yield lower than 40 kg/day (888 lb/day; +15%), cows with high BCS at parturition (+ 15%), and in cows with a low somatic cell count (+ 10%). Taken together, hormonal treatment inducing follicular turnover, combined with efficient cooling, appears to improve summer and autumn fertility, mainly in first-calf heifers.

Conclusion

Milk production and reproductive performance are being depressed during summer heat stress. Efficient cooling is capable of substantially improving milk yield to levels close to those of winter milk production. However, summer conception improved slightly with cooling, and additional hormonal treatments are required to further raise summer fertility. Five hormonal approaches aimed at improving the fertility of cooled cows in the summer were examined. Exogenous progesterone post AI improved conception mainly of cows with low body conditions and those with uterine disease post-partum. Injection of GnRH at onset of estrus has the potential to increase summer fertility, but it is not feasible to use at this time. The Ovsynch protocol is capable of increasing pregnancy rates, and it decreases the days open. Use of embryo transfer improved summer fertility, but its use is limited at present, compared with the conventional AI. Enhanced removal of heat-induced impaired follicles from the ovaries improved fertility, mainly of first-calf heifers. The use of a combination of two treatments could be beneficial and warrants examination.

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