



## Effect of Improved Cooling System on Reproduction and Lactation in Dairy Cows under Tropical Conditions

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**ABSTRACT :** The effects of utilizing evaporative cooling system equipped with tunnel ventilation on postpartum ovarian activities, energy balance and milk production of early lactating dairy cows under hot and humid climates were studied from parturition to 22 wk postpartum. Thirty-four crossbred Holstein-Friesian (93.75% HF×6.25% *Bos indicus*) primiparous cows were randomly assigned to one of two groups. Cooled cows (n = 17; treatment) were housed in the tunnel ventilated barn equipped with evaporative cooling system and uncooled (n = 17; control) were housed in the naturally ventilated barn without supplemental cooling system. Cooled cows had greater (p<0.05) dry matter intake and milk production than uncooled cows. Days to the energy balance (EB) nadir did not differ between groups. However, days to equilibrium EB for uncooled cows was longer (p<0.05) than for cooled cows. There was no significant difference in postpartum anovular condition between cooled and uncooled cows. The interval from parturition to first postpartum ovulation did not differ between groups (31.4±4.3 and 26.1±3.6 day, respectively). These results suggest that the evaporative cooling and tunnel ventilation has the potential to decrease the severity of heat stress and improve both milk production and metabolic efficiency during early lactation without affecting reproductive function in dairy cows under hot and humid climates. (**Key Words :** Evaporative Cooling, Energy Balance, Milk Production, Ovarian Activity, Tropical Condition, Dairy Cows)

### INTRODUCTION

Climatic conditions in the tropic are such that the hot season is relatively long, there is intense radiant energy for an extended period of time, and there is generally high relative humidity. Thus heat stress is chronic in nature there is often little relief from the heat during the night, and intense bursts of combined heat and humidity further depress performance. Thailand is located in a tropical area with high temperatures and humidity. Crossbred Holstein dairy cattle are popular because, during times of high environmental thermal stress, their milk production and reproductive efficiency are not depressed as purebred Holstein cattle. However, these crossbred cattle were inseminated with purebred Holstein frozen semen to improve milk production. When the genetic potential for milk yield has improved and the predominant dairy breed has become the Holstein, the impact of heat stress on

production and reproduction has increased.

Heat stress has a significant impact on dairy cattle in hot and humid climates. The most noticeable response to heat stress is reduced feed intake, reduced milk yield, reduced activity, and increased respiration rate and water intake. Because many dairy cows are unable to consume enough feed to meet energy demands during early lactation, they typically mobilize body reserves to maintain their milk production until the intake of feed can match or exceed nutritional requirements, thus, entering a state of negative energy balance (NEB) (Butler and Smith, 1989; Nebel and McGilliard, 1993). In heat stressed dairy cows there is a reduction in dry matter intake (DMI) (Fuquay, 1981), which prolongs the period of NEB. Negative energy balance leads to decreased plasma concentration of insulin, glucose and insulin-like growth factor-1 (IGF-1), and increased plasma concentrations of growth hormone and nonesterified fatty acid (NEFA) (Lucy et al., 1992). All of these metabolic hormones can affect reproduction. In an attempt to minimize these effects, a more economic method that reduces the effect of heat stress is evaporative cooling. Several studies have shown that the housing systems in hot and dry climates can be modified by the use of evaporative

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cooling and improve both milk production and reproductive efficiency of dairy cows (Flamenbaun et al., 1986; Armstrong et al., 1993; Smith et al., 1993). However, there are questions regarding the effectiveness of evaporative systems in climates with high relative humidity.

The objective of this trial was to study the impact of heat stress on postpartum reproductive performance and milk production and evaluate the effects of utilizing tunnel ventilation and an evaporative cooling system for improving postpartum ovarian activities, energy balance and milk production of early lactating dairy cows in a hot and humid climatic conditions.

## MATERIALS AND METHODS

This experiment was conducted at an experimental farm in the Veterinary Student Training Center, Faculty of Veterinary Science, Chulalongkorn University, Nakhorn Pathom that is located in the central part of Thailand (latitude 13°N and longitude 99°E).

### Experimental animals and sample collection

Thirty-four crossbred Holstein-Friesian (93.75% HF × 6.25% *Bos indicus*) primiparous cows were used for this experiment which began after calving to 22-wk postpartum. Cows were assigned randomly to one of two housing treatments based upon their calving date and body weight. Cooled cows ( $n = 17$ ; treatment) were housed in the tunnel ventilated tie-stall barn, equipped with an evaporative cooling system and uncooled cows ( $n = 17$ ; control) were housed in a naturally ventilated tie-stall barn without a supplemental cooling system.

The experimental animal housing was a 20 × 10 m housing unit, divided into two parts. One half of the animal house was an open shed that was used to study the control animals simultaneously, while the other half was fitted with an evaporative cooling system. The tunnel ventilation barn equipped with an evaporative cooling system was a 20 × 5 m housing unit, fitted out with 5 m cooling pads at one end, at the east, and two 1.5 m 1 hp exhaust fans at the opposite end, enclosing the side with heavy plastic (polyethylene). The ceiling in this barn was 2.75 m high and constructed with heavy plastic (polyethylene). Fresh air was cooled as it entered the barn through the cooling pads that were kept wet with recirculating water. This cooling system was set to operate when the temperature reached 27°C or higher. The average temperature, relative humidity and temperature-humidity index (THI) in the tunnel ventilated barn were 26.5 ± 0.1°C, 86.5 ± 0.3% and 78.0 ± 0.2, respectively. The average temperature, relative humidity and THI in the outside barn were 31.4 ± 0.1°C, 74.6 ± 0.8% and 83.1 ± 0.2, respectively. THI was calculated according to the formula:

$$\text{THI} = 0.72 (C_{\text{dry}} + C_{\text{wet}}) + 40.6$$

Where  $C_{\text{dry}}$  is dry bulb temperature (°C) and  $C_{\text{wet}}$  is wet bulb temperature (°C) (McDowell, 1972 cited by Hsia and Lainez, 2004).

The cows were individually fed a total mixed ration (TMR) *ad libitum* and were allowed continuous access to water. The TMR was composed of corn silage and concentrate. The mean chemical composition of the TMR was 1.6 Mcal of  $NE_L$ /kg, 17.9% CP, 1.7% Ca and 1.3% P (DM basis). Daily feed intake was recorded and the diet was sampled weekly for analysis. Weekly body weights were recorded. Cows were milked twice daily (05.00 and 15.00 h) and the milk yield was recorded. Milk samples were collected weekly during successive AM and PM milking and were analyzed for percentage milk fat, protein, lactose and solids not fat (SNF) (Milko-Scan 133B, N.Foss Electric, Denmark). A 4 percent fat corrected milk (4% FCM) was calculated following equations (NRC, 1989): 4% FCM = (0.4) (kg of milk) + 15 (kg of fat).

Blood samples (10 ml) were collected twice weekly at 3- to 4-d intervals by jugular venipuncture from 1 to 12 wk postpartum. After collection in tubes containing EDTA the blood was centrifuged at 3,000 × g for 10 min. Plasma sample was decanted and stored frozen at -20°C until subsequent analysis.

The concentration of progesterone in plasma was determined in all samples, using a solid phase RIA kit (Coat-A-Count Progesterone, Diagnostic Products Corporation, Los Angeles, CA, USA). The concentration of nonesterified fatty acid (NEFA) was determined in weekly plasma samples by an enzymatic method, using NEFA C kits (Wako Pure Chemical Industries Ltd., Osaka, Japan).

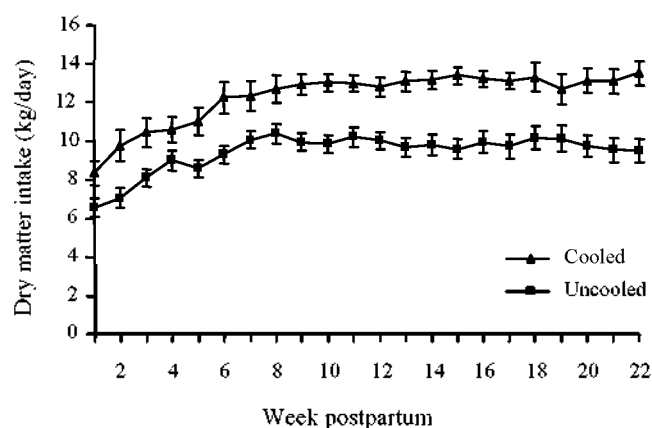
### Reproductive measures

The reproductive health of all cows was monitored every week by palpation of the reproductive tract per rectum and ultrasonography. The ovaries of cows were scanned weekly by transrectal ultrasonography using a linear array, ultrasound scanner equipped with a 5.0 MHz rectal probe (Aloka SSD500, Tokyo, Japan), starting at 3 wk and continuing through to 12 wk postpartum in order to measure follicles and determine the presence of a corpus luteum. Ultrasonography also attempted to analyze the incidence of anovulation or follicular cysts.

Calving to first ovulation interval was defined by the first increase in plasma progesterone ( $\geq 1.0$  ng/ml) after calving; ovulation was assumed to have occurred 7 d before elevation of the progesterone concentration.

### Energy balance calculations

Weekly EB was calculated for the first 12 wk of lactation for all cows according to their daily milk production, DMI, weekly BW measurements, weekly milk fat tests (weighted averages derived from analysis of the



**Figure 1.** Weekly changes in DMI for the cooled ( $\blacktriangle$ ) and uncooled ( $\blacksquare$ ) cows during the first 22 week postpartum. Each symbol represents the mean DMI of the cows in that group for that week of lactation. DMI were different between groups ( $p < 0.05$ ).

AM and PM samples), and the calculated net energy ( $NE_L$ ) value of each diet utilizing the following equations (NRC, 1989):

$$NE_C = NE_L \text{ per kilogram of DM} \times \text{DMI}$$

$$NE_L = 0.74(\text{milk (kilograms)} \times 0.4 + \text{milk fat (kilograms)} \times 15)$$

$$NE_R = BW^{0.75}(0.08) + NE_L$$

$$EB = NE_C - NE_R$$

Where  $NE_C$  = net energy consumed,  $NE_L$  = net energy for lactation,  $NE_R$  = net energy required, and EB = energy balance.

Energy balance was expressed as mega calories of NE per day for each week and could be positive or negative. The lowest numerical value within the actual EB profile of each cow was designated as the day of the EB nadir.

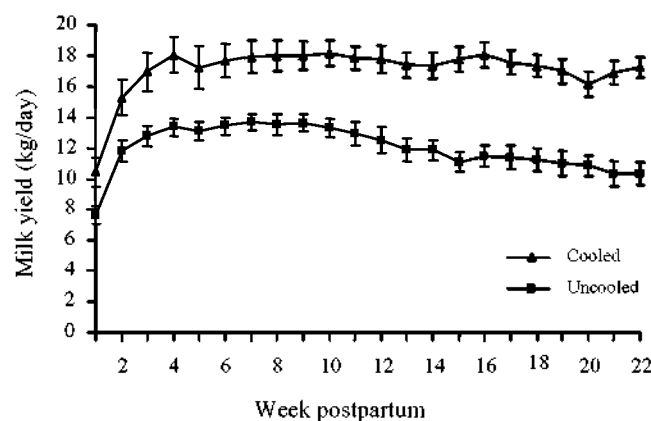
### Statistical analyses

All statistical analyses were performed using SPSS 11.0 (SPSS Inc., Chicago, IL, USA). Data involving repeated measurements were analyzed by repeated measures ANOVA. The statistical model included week after parturition and treatment groups as independent variable. Single mean comparisons were analyzed by the Student's *t* test. Proportional data were analyzed using Chi-square procedures. The level of significance was set at  $p \leq 0.05$ .

## RESULTS

### Dry matter intake and daily milk yield

Dry matter intake expressed as kilograms per day (kg of



**Figure 2.** Weekly changes in milk production for the cooled ( $\blacktriangle$ ) and uncooled ( $\blacksquare$ ) cows during the first 22 week postpartum. Each symbol represents the mean yield of the cows in that group for that week of lactation. Yields were different between groups ( $p < 0.05$ ).

DM/day) was greater ( $p < 0.05$ ) in cooled ( $12.0 \pm 0.2$  kg/d) than uncooled cows ( $9.1 \pm 0.2$  kg/d). DMI increased ( $p < 0.05$ ) from wk 1 to 12 of lactation in both groups of cows but treatment  $\times$  week postpartum did not affect ( $p > 0.05$ ) it (Figure 1).

Daily milk yield was greater ( $p < 0.001$ ) in cooled ( $16.9 \pm 0.3$  kg/d) than uncooled ( $12.6 \pm 0.2$  kg/d) cows. Daily milk yield increased ( $p < 0.001$ ) from wk 1 to wk 8 of lactation in both groups of cows but treatment  $\times$  week postpartum did not affect ( $p > 0.05$ ) daily milk yield (Figure 2). The 4% FCM also differ ( $p < 0.001$ ) between cooled and uncooled cows. Cooled cows had more persistent milk production than uncooled cows. Milk composition did not differ ( $p > 0.05$ ) between the groups of cows over the study period.

### Postpartum interval to first ovulation (POI)

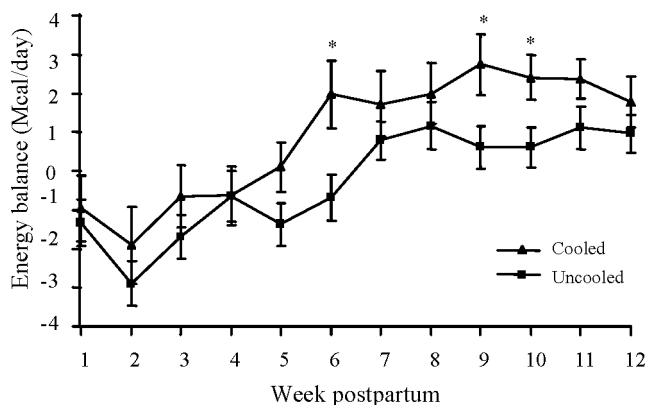
Interval until the onset of the ovarian cycle was studied in 34 cows. Five cows did not show any ovulation postpartum (i.e., first rise in plasma  $P_4 \geq 1.0$  ng/ml) within the 12-wk study period. Thus, 29 cows were included in the analysis of interval from parturition to first ovulation. The proportion of cows which showed first ovulation postpartum within 12-wk study did not differ ( $p > 0.05$ ) between the cooled (88.2%) and the uncooled (82.4%) cows. The average days to first ovulation did not differ ( $p > 0.05$ ) between cooled and uncooled cows (Table 1).

### Energy balance and body weight

The energy balance of cows in both groups is presented in Figure 3. Week postpartum ( $p < 0.001$ ) and treatment ( $p < 0.001$ ) affected EB but treatment  $\times$  week postpartum was not significant. Cows in both groups entered into NEB immediately after calving. During the 12-wk study, an averaged EB was greater ( $p < 0.001$ ) in cooled ( $0.916 \pm 0.194$

**Table 1.** Nadir of NEB, days to nadir of NEB, days to equilibrium EB and days to first ovulation of cooled and uncooled cows during the 12 week study (mean±SEM)

	Cooled (Inside)	Uncooled (Outside)	p value
Number of animal (N)	15	14	
Nadir of NEB (Mcal/d)	-2.8±0.8	-3.7±0.4	0.404
Days to nadir of NEB (days)	19.1±2.7	20.0±2.3	0.810
Days to equilibrium EB (days)	39.7±5.0	53.0±4.1	0.040
Days to first ovulation (days)	31.4±4.3	26.1±3.6	0.357

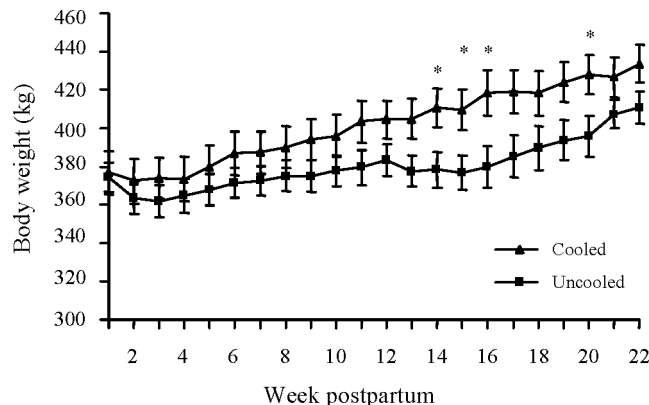
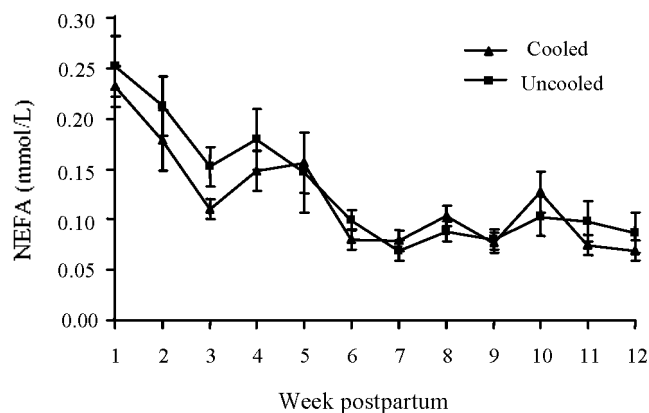
**Figure 3.** Weekly changes in energy balance for the cooled (▲) and uncooled (■) cows during the first 12 week postpartum. There were no significant differences between groups ( $p>0.05$ ). Each symbol represents the mean energy balance of the cows in that group for that week of lactation. Differences ( $p<0.05$ ) are indicated by (\*).

Mcal/day) than uncooled cows ( $-0.268\pm 0.195$  Mcal/day). The week of EB nadir was at wk 2 in both groups and the degree of EB nadir did not differ significantly ( $p>0.05$ ) between the groups, although the average was lower in uncooled than cooled cows. After reaching the EB nadir, uncooled cows required more days to reach a positive energy balance than the cooled cows. The first week that EB was greater than zero was at wk 5 in cooled cows and at wk 7 in uncooled cows.

During the 12 wk of lactation, average body weight (BW) of postpartum cows was greater in cooled ( $389.1\pm 2.8$  kg) than uncooled ( $372.5\pm 2.8$  kg) cows, but BW was not affected ( $p>0.05$ ) by treatment×week postpartum. In both groups of cows, BW decreased between wk 1 and 4, and increased between wk 5 and 22 (Figure 4).

#### Nonesterified fatty acid (NEFA)

Plasma NEFA concentrations did not differ ( $p>0.05$ ) between the cooled and uncooled cows over the 12-wk study. Also the interaction of treatments and week postpartum did not affect ( $p>0.05$ ) concentrations of NEFA. Concentrations of NEFA average  $0.122\pm 0.007$  mmol/L for cooled cows and  $0.133\pm 0.007$  mmol/L for uncooled cows. Plasma NEFA concentrations decreased ( $p<0.05$ ) with week postpartum for both groups of cows. Concentrations of

**Figure 4.** Weekly changes in average body weight for the cooled (▲) and uncooled (■) cows during the first 22 week postpartum. Each symbol represents the mean body weight of the cows in that group for that week of lactation. Differences ( $p<0.05$ ) are indicated by (\*).**Figure 5.** Changes in plasma NEFA concentrations for the cooled (▲) and uncooled (■) cows during the first 12 week postpartum. Each symbol represents the mean plasma NEFA concentrations of the cows in that group for that week of lactation. There were no significant differences between groups ( $p>0.05$ ).

NEFA decreased ( $p<0.05$ ) from wk 1 to 6 and remained unchanged between wk 6 and 12 in both groups of cows (Figure 5).

## DISCUSSION

Environmental modifications, as described in materials and methods, led to a decrease the ambient temperature and an increase in the relative humidity. THI in the tunnel

ventilated barn decreased as compared to the outside barn. However, THI in the tunnel ventilated barn still exceeded the critical point of 72, suggesting that the cows were exposed continuously to conditions conducive to heat stress. In hot dry climatic conditions, this system would work well and evaporative cooling has already been used very successfully to cool such dairy cows (Ryan et al., 1992; Ali et al., 1999), but in high humidity locations its effectiveness would be limited by the evaporation potential. In the present study during the hottest portion of the day, the outside relative humidity dropped to a level that allowed for maximum evaporation potential, making the system effective for reducing the severity of heat stress. Dairy cows housed in the evaporative cooling system tended to be less stressed and had greater milk production than uncooled cows.

High ambient temperatures cause stress in dairy cows with decreasing DMI and milk yield (Kamiya et al., 2006), which supported our result. A reduction in DMI decreases the nutrients available for milk synthesis. McGuire et al. (1989) reported that a portion of the negative effects of heat stress on milk production could be explained by decreased nutrient intake and decreased nutrient uptake by the portal drained viscera of the cow. Blood flow which moves to peripheral tissues for cooling purposes may alter nutrient metabolism and contribute to lower milk yields during hot weather.

In the present study, DMI in uncooled cows was lower than in cooled cows. This resulted in uncooled cows having a prolonged period of NEB. An average EB in cooled cows was significantly greater than uncooled cows. However, days to the EB nadir and the degree of EB did not differ significantly between the groups. After that both cooled and uncooled cows improved the EB as week postpartum progressed, but cooled cows attained a more positive EB at wk 3 to 12 postpartum than uncooled cows. Probably these uncooled cows were not able to compensate for their higher maintenance requirements. The state of NEB is further characterized by changes in individual metabolites, most noticeably increases in plasma NEFA in early lactation (Staples et al., 1990). In the present study, the highest concentration of NEFA was observed wk 1 postpartum in both groups, which may indicate that these cows had high fat mobilization during this period, and decreased dramatically until wk 6 and 7 postpartum in both cooled and uncooled cows. When compared with the value wk 1 postpartum, the concentration of NEFA decreased by 65% in cooled cows and 72% in uncooled cows.

In the present study, we did not find any follicular cysts in both groups of cows. However, there was anovulation during 12-wk study in both cooled and uncooled cows (11.8 and 17.6%, respectively). Some recent studies have reported

an incidence of anovulation in dairy cattle ranging from 18 to 29% based on serum progesterone concentrations (Cartmill et al., 2001; Moreira et al., 2001; Pursley et al., 2001). Postpartum cows will begin to cycle once LH pulsatility reaches a critical level. The increase in LH pulsatility stimulates the maturation of a dominant follicle (Mihm and Austin, 2002). The dominant follicle produces estradiol that reaches a threshold level to trigger an LH surge. The cow will have an LH surge and ovulate as long as the LH surge mechanism is established. The anovular conditions in this study may be due to non-existence of an LH surge which is needed for ovulation and resultantly the animal remains anovulated. As a mechanism of the anovular conditions caused by stress that exert inhibitory effects on the hypothalamus and follicle, respectively, and subsequently LH and follicle stimulating hormone (FSH) surges are blocked, then finally ovulation is suppressed (Kawate, 2004). Several studies have shown that the energy balance postpartum affects follicular development and ovulation (Butler and Smith, 1989; Beam and Butler, 1997; Butler, 2003). The NEB results in a parallel reduction in LH pulsatility, with consequent compromised follicular steroid output and anovulation.

In the present study, we found that cooling did not improve ovarian activities. However, on the other hand, the cooling has increased milk production, without affecting reproductive performance adversely, exhibiting the beneficial affect of the cooling regime. In addition, we founded that the rate of return on investment in cooling equipment and additional feed plus electric costs of this cooling system, showed it was profitable in hot and humid conditions. The combined effect of higher milk production and increasing lactation persistency, with minimal costs could improve the financial status of dairy operations.

## CONCLUSION

These results suggest that the evaporative cooling and tunnel ventilation system has the potential to decrease the severity of heat stress and improve both milk production and metabolic efficiency during early lactation without affecting reproductive function in dairy cows under hot and humid climatic conditions. However additional research is needed to determine the effects of tunnel ventilation and evaporative cooling system on postpartum reproductive performance when compared to conventional methods of cow cooling.

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