CHAPTER 4

RESULTS

This study was conducted beginning April 2004 and continuing through May 2005. All cows were studied from parturition to 22 week postpartum. There was no significant difference in the environmental conditions, milk production and conception rate among calving seasons (Table 2); therefore, all data from three calving seasons were combined into one group in each housing unit. One cow in both the control and treatment groups had foot problems; therefore, data for these 2 cows were excluded from the statistical analyses.

Table 2. The environmental conditions, milk production and conception rate among calving seasons.

	Hot (Apr-Jun)	Wet (Jul-Oct)	Cool (Nov-Feb)	Total
Environmental conditions:				
Mean maximum air temperature				
Control (°C)	35.1 ± 2.5	34.5 ± 1.6	33.9 ± 2.0	34.4 ± 2.0
Treatment (°C)	29.3 ± 0.7	29.1 ± 0.8	27.2 ± 1.5	28.4 ± 1.5
Milk production: (First 22 week of lactation)				
Control (kg/day)	13.2 ± 2.3	11.1 ± 2.9	12.3 ± 3.1	12.0 ± 3.0
Treatment (kg/day)	17.5 ± 3.7	17.4 ± 4.8	16.1 ± 3.6	17.1 ± 4.2
Reproduction: (First conception rate)				
Control (%)	20.0(1/5)	16.7(1/6)	16.7(1/6)	17.6(3/17)
Treatment (%)	25.0(1/4)	16.7(1/6)	33.3(2/6)	25.0(4/16)

Environmental conditions and Physiological responses

The air temperatures increase during the day and decrease in the evening until the next morning (Figure 2). As the air temperature rises during the day, the relative humidity decreases. The average daily minimum and maximum temperatures in the evaporative cooled, tunnel ventilated barn were 24.2±0.1 and 28.4±0.1^{o}C, respectively and 24.7±0.1 and 34.4±0.1^{o}C, respectively in the outside barn. Daytime peak temperature in the tunnel barn average 6.0±0.2^{o}C lower ($P<0.05$) than that in the outside barn.

The average daily temperature in the evaporative cooled, tunnel ventilated barn was lower ($P<0.05$) than that in the outside barn.

The average daily relative humidity in the outside barn increased in the morning and decreased in the afternoon, but the average daily relative humidity in the evaporative cooled, tunnel ventilated barn did not differ between AM and PM milking. (Figure 3)

The average daily THI in the morning and afternoon in the evaporative cooled, tunnel ventilated barn was lower ($P<0.05$) than that in the outside barn. (Table 3)

The exposure to the conditions of moderate heat stress (THI$\geq$79) that occurred in the outside barn decreased to a condition of mild heat stress (THI$<$79) in the tunnel ventilated barn, during the day. (Figure 4)

Cows housed in the tunnel barn, had lower ($P<0.05$) rectal temperatures and respiration rates than cows housed outside. (Table 2)

There was no treatment and week postpartum effect ($P>0.05$) or interaction ($P>0.05$) between treatments and weeks postpartum, on serum cortisol. Concentrations of cortisol averaged 17.2 $\pm$ 1.0 and 15.9 $\pm$ 1.0 ng/ml in cooled and uncooled cows, respectively, and did not differ ($P=0.317$) significantly.

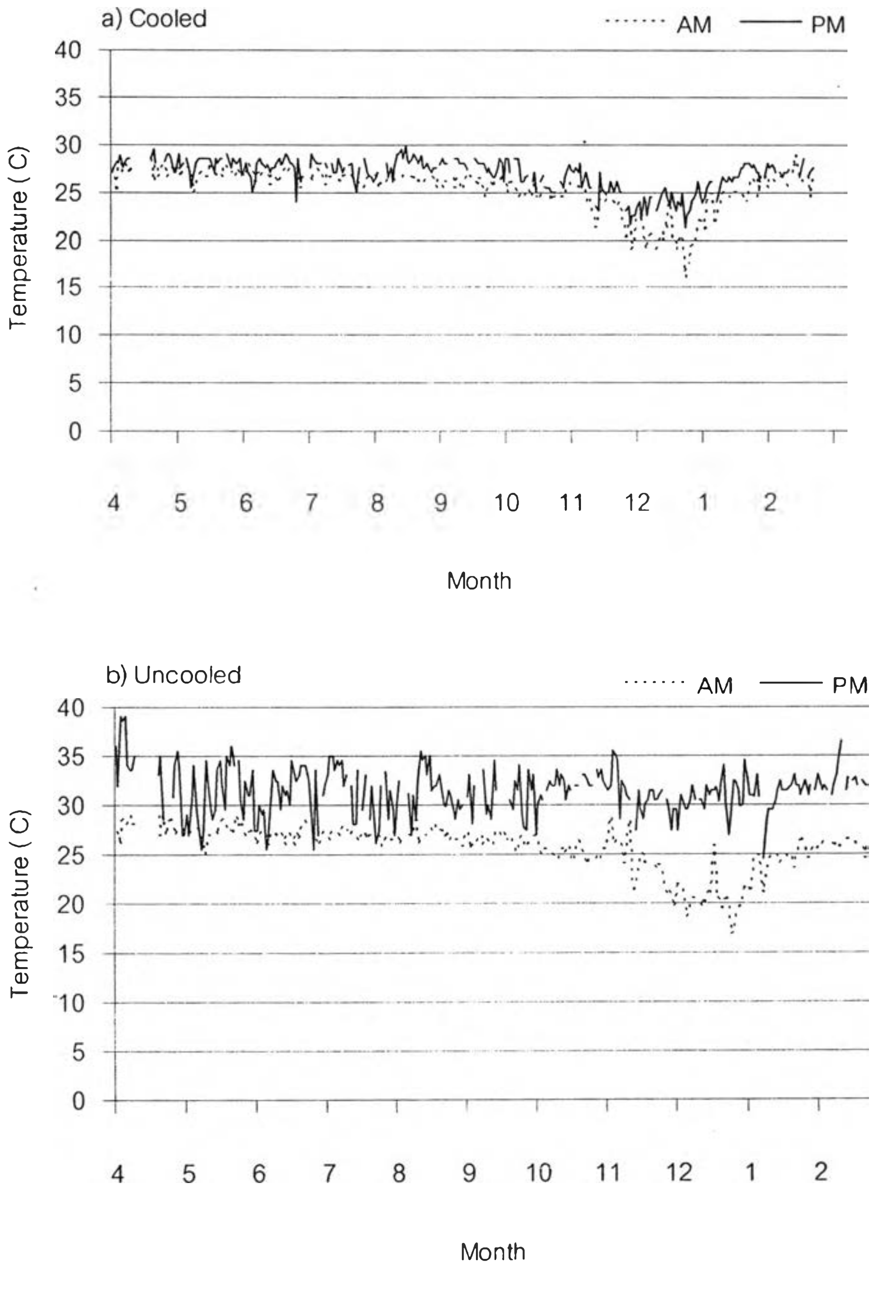

Figure 2. Changes in daily air temperature at AM and PM milking in a tunnel ventilated barn equipped with an evaporative cooling pad system (cooled; a) and a naturally ventilated barn without a supplemental cooling system (uncooled; b) during April 2004 to February 2005.

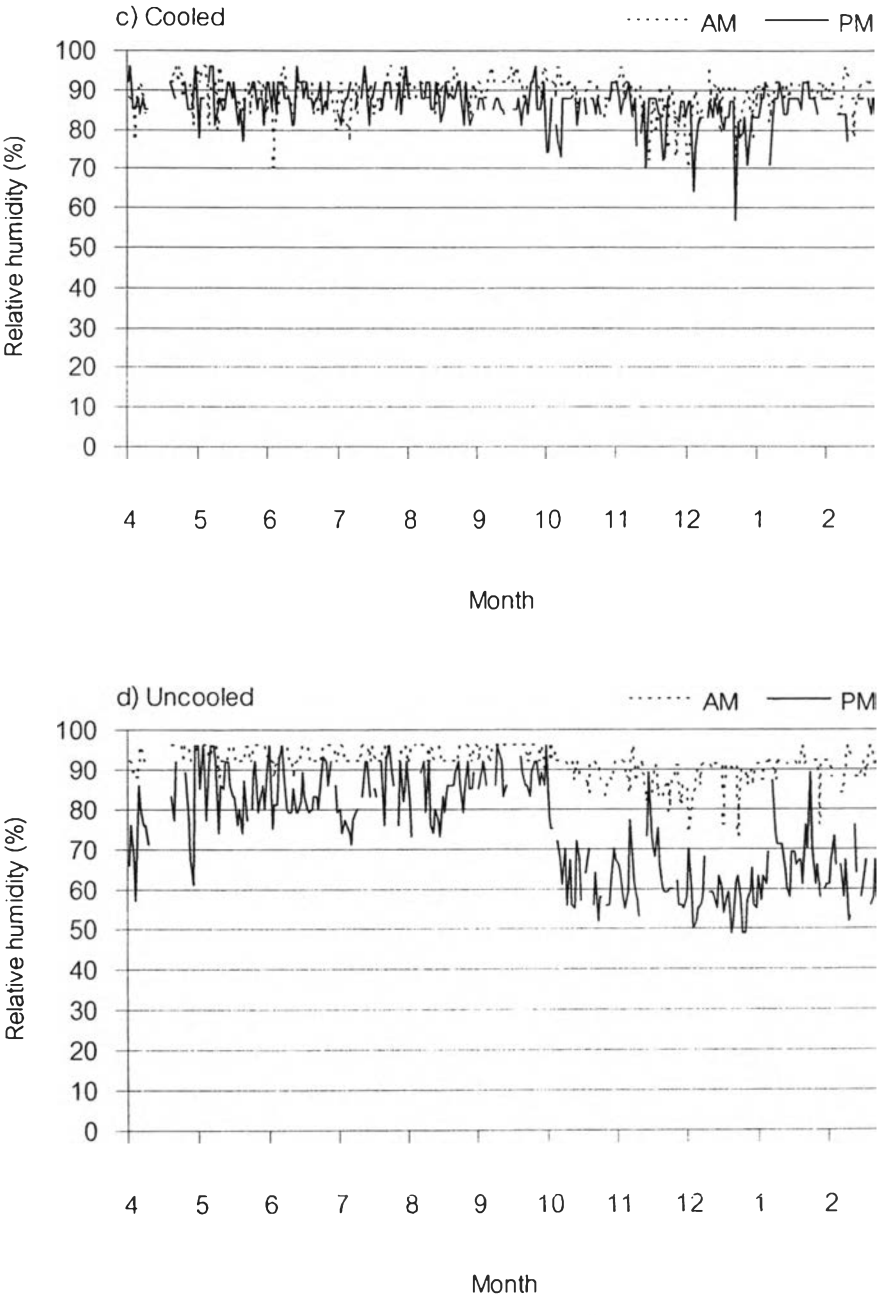

Figure 3. Changes in relative humidity at AM and PM milking in a tunnel ventilated barn equipped with an evaporative cooling pad system (cooled; c) and a naturally ventilated barn without a supplemental cooling system (uncooled; d) during April 2004 to February 2005.

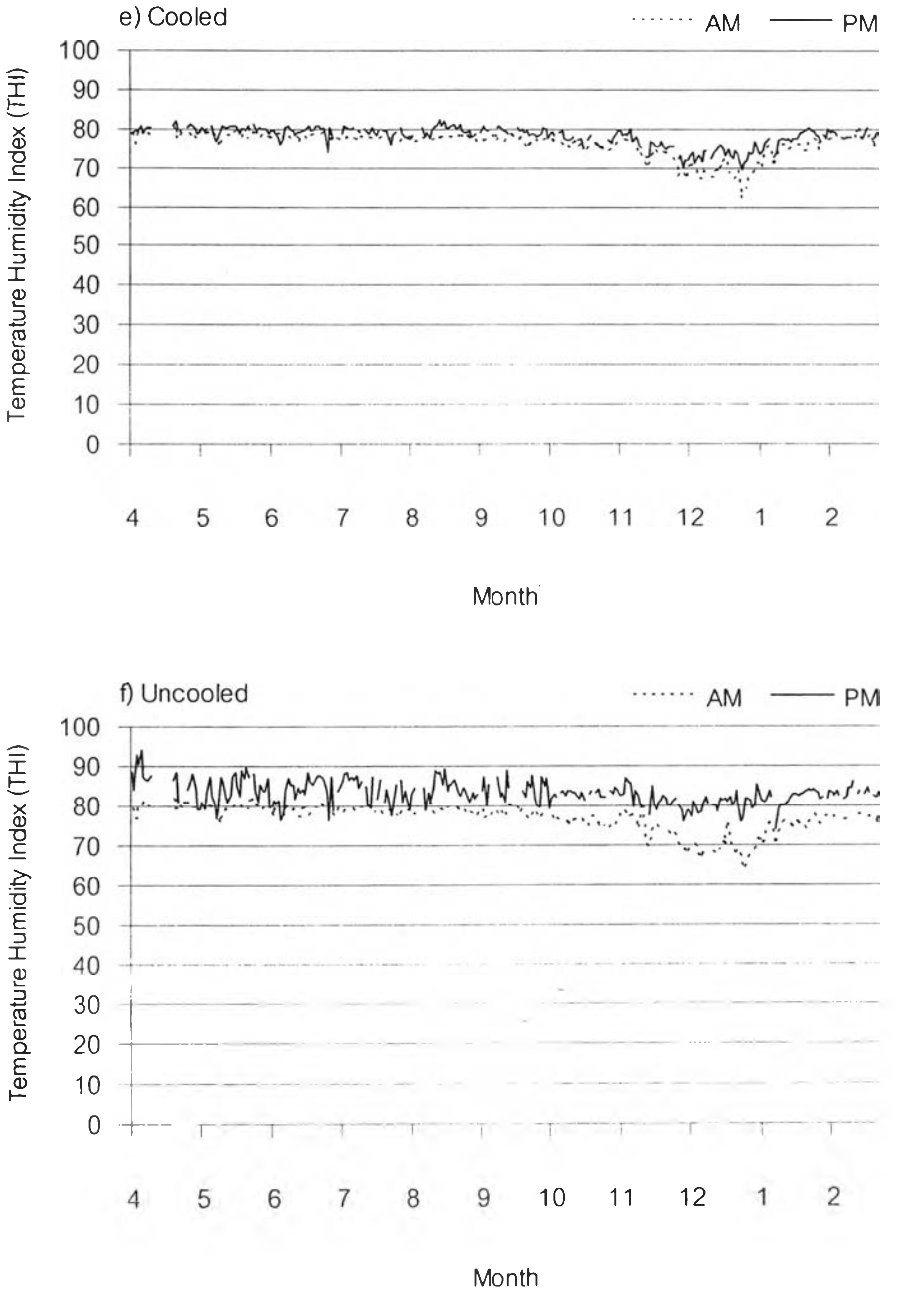

Figure 4. Changes in THI at AM and PM milking in a tunnel ventilated barn equipped with an evaporative cooling pad system (cooled; e) and a naturally ventilated barn without a supplemental cooling system (uncooled; f) during April 2004 to February 2005.

Table 3. The environmental measurement and physiological responses of dairy cows in the experimental housing. (Mean±S.E.M.)

	Cooled (inside)	Uncooled (outside)	P-value
Number of animals (n)	17	17	
Environmental measurement :			
Daily minimum temperature (°C)	24.2±0.1	24.7±0.1	*
Daily maximum temperature (°C)	28.4±0.1	34.4±0.1	*
AM milking			
Daily mean temperature (°C)	25.3±0.1	25.6±0.1	*
Daily mean relative humidity (%)	88.5±0.3	91.6±0.2	*
Daily mean THI	76.0±0.2	76.7±0.2	*
Rectal temperature (°C)	38.4±0.0	39.2±0.1	*
Respiratory rate (breaths/min)	42.7±1.4	54.5±1.4	*
PM milking			
Daily mean temperature (°C)	26.5±0.1	31.4±0.1	*
Daily mean relative humidity (%)	86.5±0.3	74.6±0.8	*
Daily mean THI	78.0±0.2	83.1±0.2	*
Rectal temperature (°C)	38.7±0.0	39.7±0.1	*
Respiratory rate (breaths/min)	46.3±1.8	68.3±2.2	*

* Means differ ($P<0.05$) between groups

Dry matter intake and Daily milk yield

Dry matter intake, expressed as kilograms per day (kg of 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 22 of lactation in both groups of cows but treatment x week postpartum did not affect (P>0.05) it. (Figure 5)

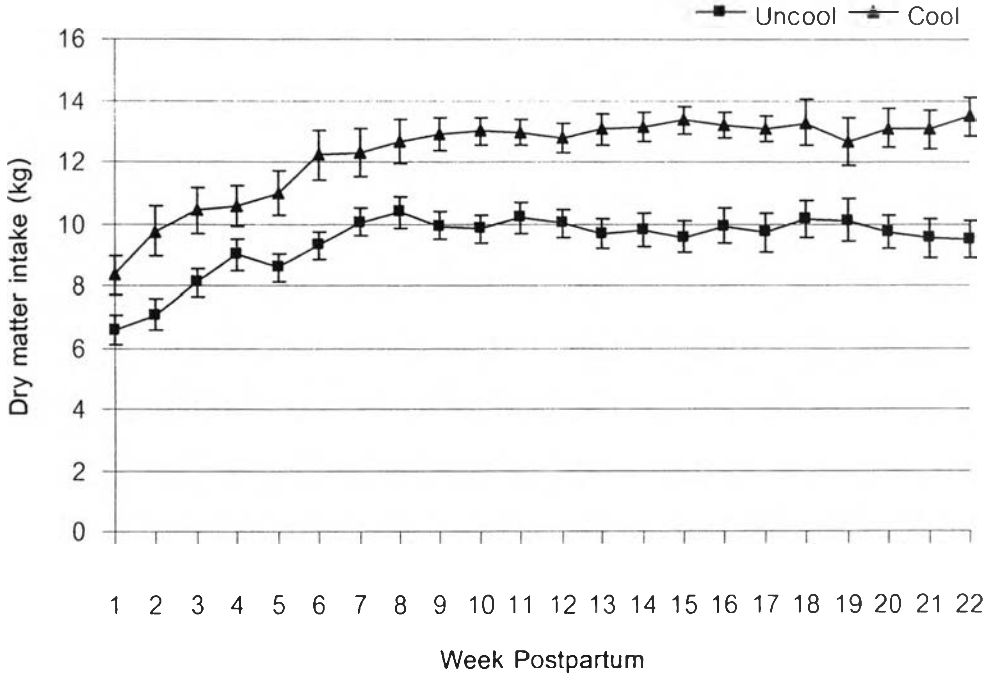

Figure 5. Weekly changes in average daily DMI for the cooled and uncooled cows during the first 22 week postpartum.

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 22 of lactation in both groups of cows but treatment x week postpartum did not affect (P>0.50) daily milk yield. (Figure 6) 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>0.50) between the groups of cows over the 12 week study. (Table 4)

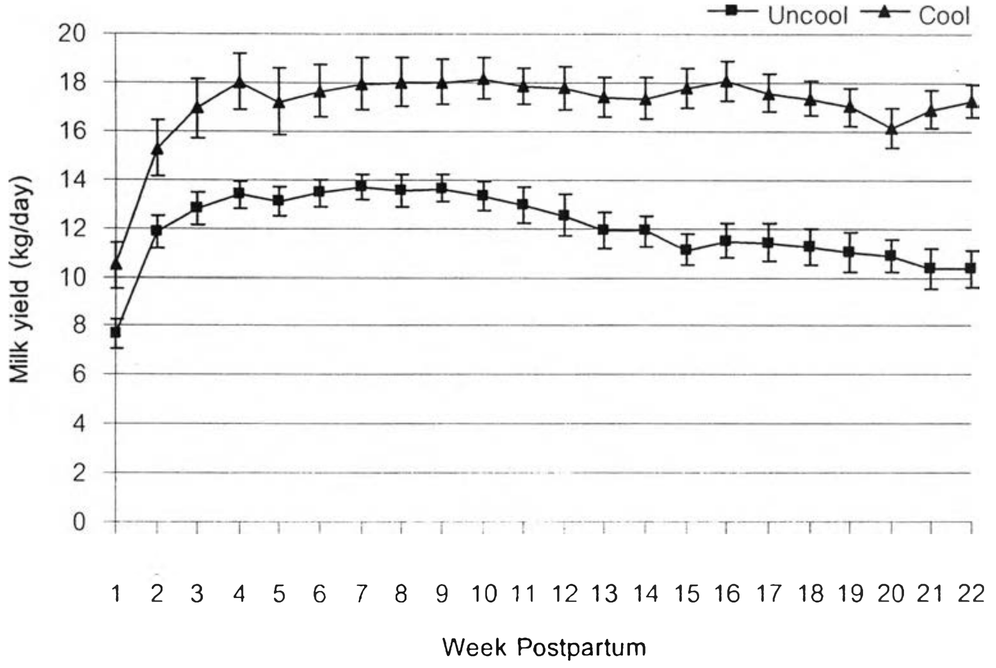

Figure 6. Weekly changes in average daily milk production for the cooled and uncooled cows during the first 22 week postpartum.

Table 4. Dry matter intake, milk production and milk composition of cooled and uncooled cows during the 12 week study.

	Cooled (inside)	Uncooled (outside)	P-value
Dry matter intake (kg/d)	12.0 ± 0.2	9.1 ± 0.2	0.001
Milk yield (kg/d)	16.9 ± 0.3	12.6 ± 0.2	0.001
Fat (%)	3.3 ± 0.06	3.4 ± 0.06	0.302
Protein (g%)	3.21 ± 0.03	3.14 ± 0.03	0.409
Lactose (g%)	5.03 ± 0.02	4.99 ± 0.02	0.114
Solid not fat (g%)	8.94± 0.04	8.85 ± 0.04	0.212

Energy balance and Body weight

The energy balance of cows in both groups is presented in Figure 7. Week postpartum ($P<0.001$) and treatment ($P<0.001$) affected EB but treatment x week postpartum was not significant. Cows in both groups entered into NEB immediately after calving. Averaged EB was greater ($P<0.001$) in cooled (0.916 ± 0.194 Mcal/day) than uncooled cows (-0.268 ± 0.195 Mcal/day). During the 12 week study, the week of EB nadir was at wk 2 in both groups and the degree of EB nadir did not differ significantly ($P>0.50$) 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.

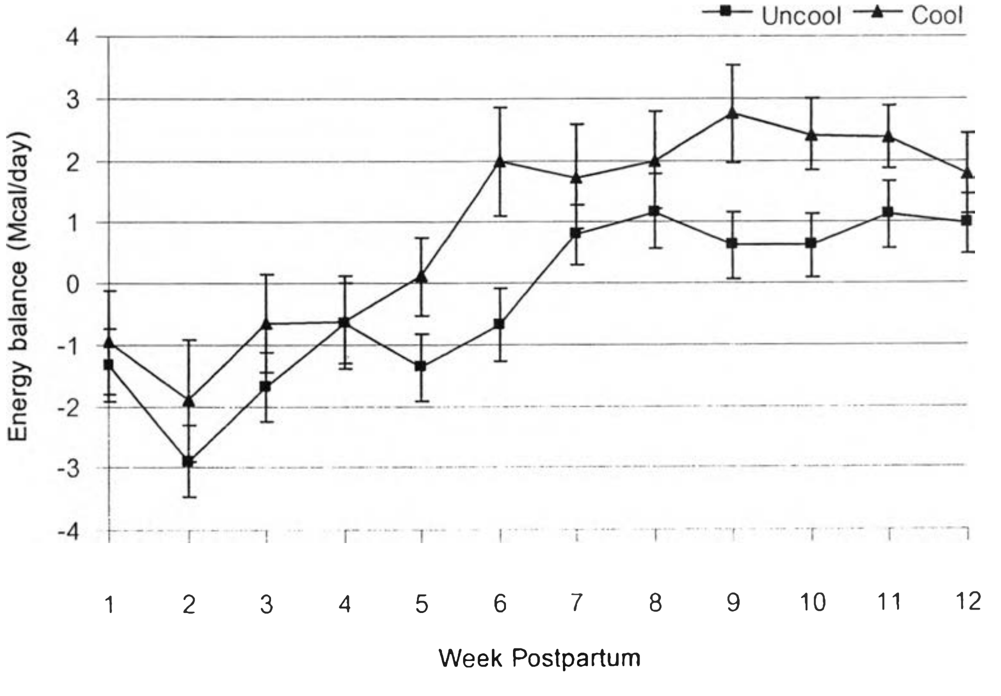

Figure 7. Weekly changes in energy balance for the cooled and uncooled cows during the first 12 week postpartum.

During the 12 week of lactation, average body weight (BW) of postpartum cows was greater ($P<0.001$) in cooled (389.1 ± 2.8 kg) than uncooled (372.5 ± 2.8 kg) cows, but BW was not affected ($P>0.50$) by treatment x week postpartum. Also weekly BW differed ($P<0.001$) among weeks postpartum. In both groups of cows, BW decreased between wk 1 and 4, and increased between wk 5 and 12. Body weight loss did not differ ($P>0.50$) between the groups of cows. (Figure 8)

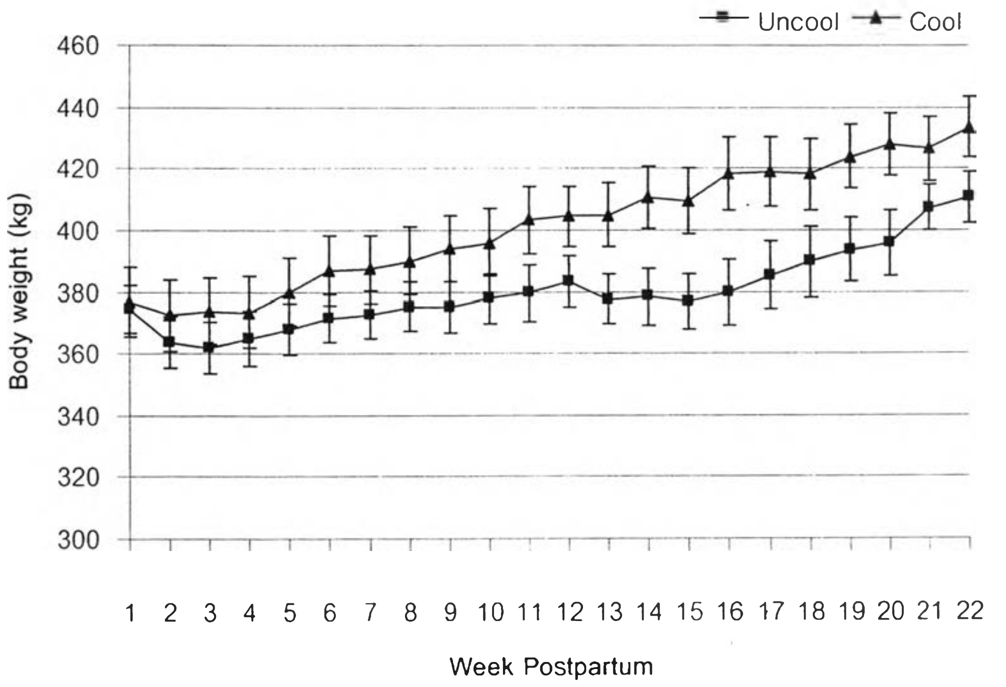

Figure 8. Weekly changes in average body weight for the cooled and uncooled cows during the first 22 week postpartum.

Nonesterified fatty acid (NEFA)

Plasma NEFA concentrations did not differ (P>0.50) between the cooled and uncooled cows over the 12 week study. Also the interaction of treatments and week postpartum did not affect (P>0.50) 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 NEFA decreased (P<0.05) from wk 1 to 6 and remained unchanged between wk 6 and 12 in both groups of cows. (Figure 9)

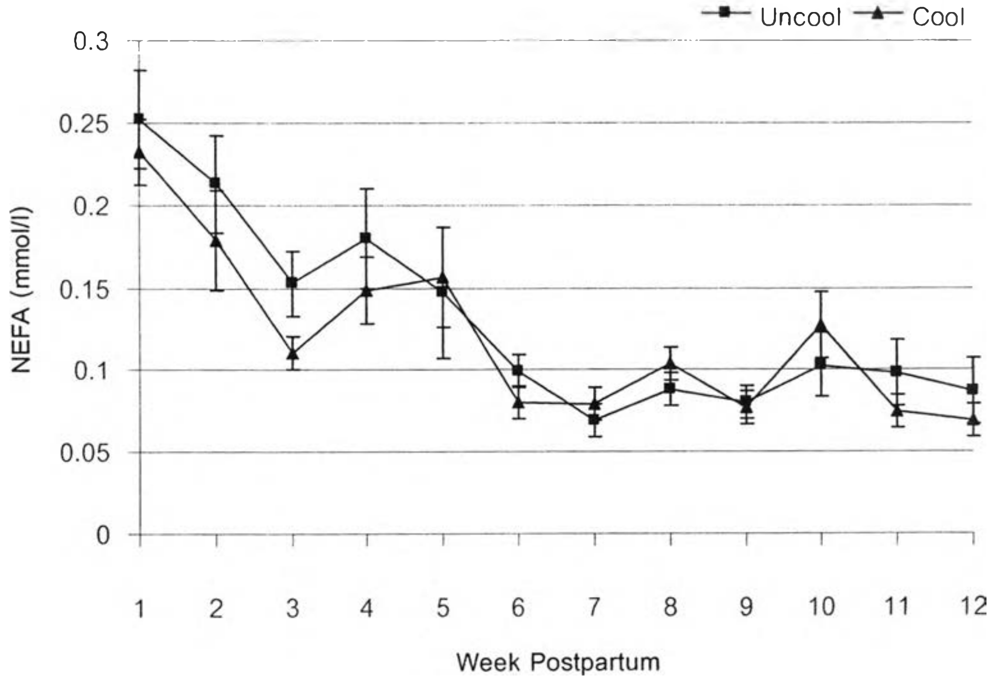

Figure 9. Changes in plasma NEFA concentrations for the cooled and uncooled cows during the first 12 week postpartum.

β-hydroxybutyrate

Concentration of β-hydroxybutyrate was greater (P<0.008) in cooled (539.7 $\pm$ 15.0 μmol/l) than uncooled (479.1 $\pm$ 15.6 μmol/l) cows. There was no week postpartum effect (P>0.50) or interaction (P>0.50) between treatments and weeks postpartum.

Insulin-like growth factor-I

Plasma IGF-I concentrations was greater (P<0.047) in cooled (94.8 $\pm$ 3.3 ng/ml) than uncooled (85.0 $\pm$ 3.4 ng/ml) cows. There was no treatment x week postpartum effect (P>0.50) on plasma IGF-I concentrations. Plasma IGF-I concentrations increased (P<0.05) with weeks postpartum. (Figure 10)

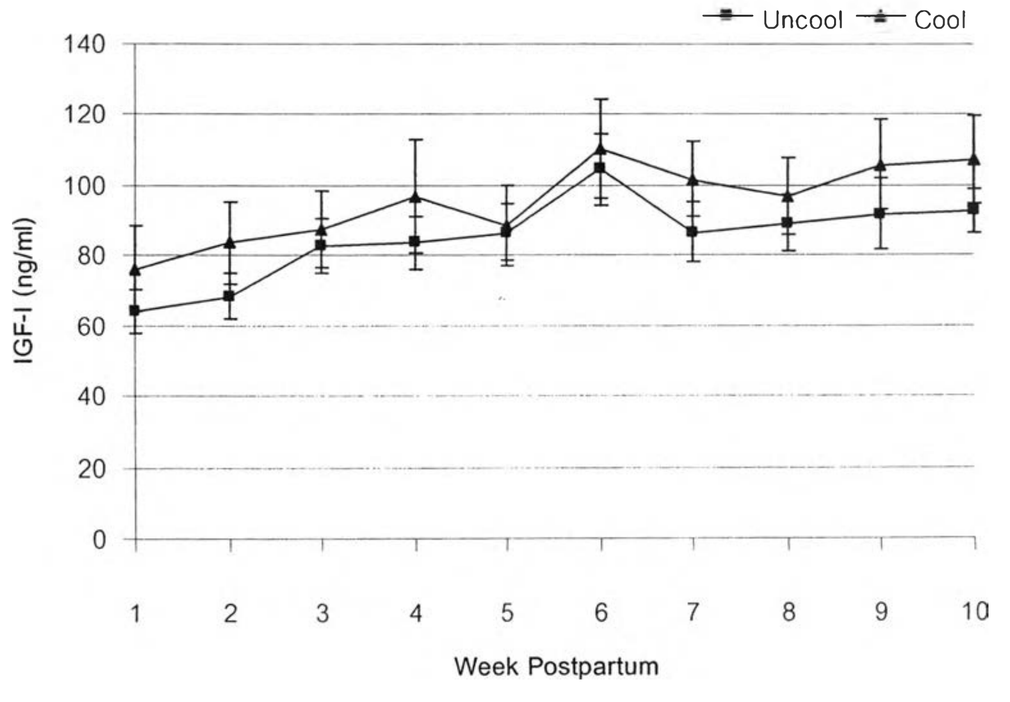

Figure 10. Changes in plasma IGF-I concentrations for the cooled and uncooled cows during the first 10 week postpartum.

Blood urea nitrogen

Blood urea nitrogen was greater ($P<0.014$) in cooled (12.8 ± 0.3 mg/dl) than uncooled (11.7 ± 0.3 mg/dl) cows. Concentrations of BUN changed ($P<0.05$) with weeks postpartum but treatment x week postpartum did not show any affect ($P>0.50$). (Figure 11)

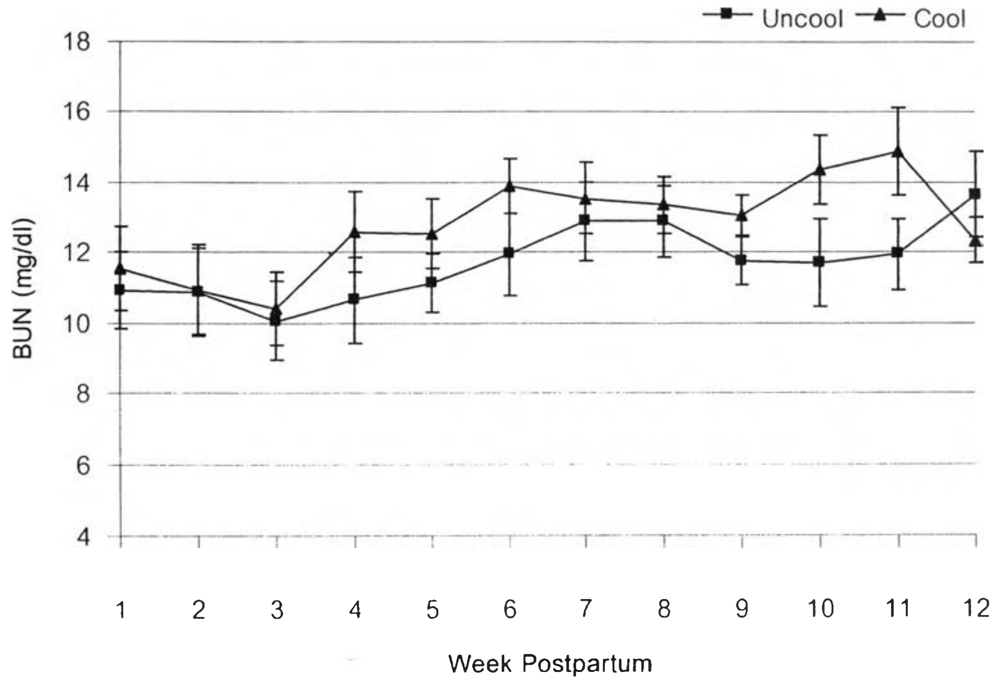

Figure 11. Changes in BUN concentrations for the cooled and uncooled cows during the first 12 week postpartum.

Postpartum interval to first ovulation

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 average days to first ovulation did not differ ($P>0.50$) between cooled (31.4±4.3 d) and uncooled (26.1±3.6 d) cows. (Table 5) The proportion of cows which showed first ovulation postpartum within 12 week study did not differ ($P>0.50$) between the cooled (88.2%) and the uncooled (82.4%) cows.

The relationships between energy balance, body weight loss and postpartum ovulation were examined by simple correlation. The nadir of NEB was positively correlated with body weight loss (r = 0.55, P<0.01) but negatively correlated (r = -0.69, P<0.01) with days to equilibrium EB. Body weight loss was negatively correlated (r = -0.49, P<0.01) with days to equilibrium EB.

Table 5. Nadir of NEB, days to nadir of NEB, days to equilibrium EB, body weight loss, and days to first ovulation of cooled and uncooled cows during the 12 week study. (Mean±S.E.M.)

	Cooled (inside)	Uncooled (outside)	P-value
Number of animals (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	0.050
Body weight loss (kg)	51.9±5.1	56.2±5.5	0.571
Days to first ovulation (day)	31.4±4.3	26.1±3.6	0.357

Correlations

In the present study air temperature was positively correlated with THI (r = 0.96, P<0.01), rectal temperature (r = 0.70, P<0.01), and respiration rate (r = 0.66, P<0.01) but negatively correlated (r = -0.47, P<0.01) with relative humidity. THI was positively correlated with rectal temperature (r = 0.71, P<0.01), and respiration rate (r = 0.65, P<0.01) but negatively correlated with relative humidity (r = -0.27, P<0.01), DMI (r = -0.23, P<0.01), and milk production (r = -0.13, P<0.05). Rectal temperature was positively correlated with respiration rate (r = 0.83, P<0.01) but negatively correlated (r = -0.35, P<0.05) with DMI. Dry matter intake was positively correlated with milk production (r = 0.74, P<0.01). (Table 6)

Table 6. Correlation coefficient among average air temperature (TEMP), relative humidity (HUMID), THI, rectal temperature (REC), respiration rate (RES), DMI and milk yield (MILK) during the first 12 week of lactation in dairy cows.

Variable	HUMID	THI	REC	RES	DMI	MILK
TEMP	-0.47**	0.96**	0.70**	0.66**	-0.12*	-0.07
HUMID		-0.27**	-0.27**	-0.31**	-0.18**	-0.09
THI			0.71**	0.65****	-0.23**	-0.13*
REC				0.83**	-0.35*	-0.04
RES					-0.23	-0.03
DMI						0.74**

**P*<0.05, ***P*<0.01

Energy balance was positively correlated with DMI (r = 0.72, P<0.01), IGF-I (r = 0.51, P<0.01), BUN (r = 0.17, P<0.01) and β-hydroxybutyrate (r = 0.11, P<0.05) but negatively correlated (r = -0.35, P<0.01) with NEFA. DMI was positively correlated with BUN (r = 0.23, P<0.01), IGF-I (r = 0.39, P<0.01), β-hydroxybutyrate (r = 0.11, P<0.05) and cortisol (r = 0.14, P<0.01) but negatively correlated with NEFA (r = -0.28, P<0.01). In present study, the number of days to first ovulation was not correlated with mean EB and blood metabolites. (Table 7)

Table 7. Correlation coefficient among average energy balance (EB), DMI, NEFA, beta-hydroxybutyrate (BH), IGF-I, BUN and first ovulation interval (OV) during the first 12 week of lactation in dairy cows.

Variable	DMI	NEFA	BH	IGF-I	BUN	OV
EB	0.72**	0.35**	0.11**	0.51**	0.17**	0.27
DMI		-0.28**	0.11**	0.39**	0.23**	-0.05
NEFA			0.04	-0.20**	-0.03	-0.00
BH				-0.06	0.13**	-0.06
IGF-I					0.04	-0.18
BUN						-0.04

**P*<0.05, ***P*<0.01

Follicular development and ovulation

There were 3 cooled and 8 uncooled cows did not ovulate within 120 h of $PGF_{2\alpha}$ treatment. The synchronization rate for cooled cows tended to be greater (P=.08) than the uncooled cows. There was an interaction of treatment by day (P < 0.05) for the diameter of the largest ovulatory follicle. The largest ovulatory follicle was initially similar between the two treatments. After that, cooled cows had a greater (P < 0.05) average diameter than the uncooled cows. (Figure 12) Cooled cows tended to have a larger (P=0.1) ovulatory follicle at time of $PGF2_{\alpha}$ treatment than the uncooled cows. There was no difference between the cooled and uncooled cows for the growth rate of the largest ovulatory follicle, after luteolysis and the interval from $PGF_{2\alpha}$ treatment to ovulation. (Table 8)

Table 8. The effect of evaporative cooling and tunnel ventilation system on follicular development, time of ovulation and the response rates of synchronized cows to GnRH and $PGF_{2\alpha}$. Results are expressed as mean±SEM.

	Cooled	Uncooled	P-value
Number of animal (n)	17	17	
Synchronization rate (%)	82.4(14/17)	52.9(9/17)	0.08
nterval to new follicular wave emergence (day)	2.2±0.1	2.3±0.2	0.55
Size of the largest ovulatory follicle at $PGF_{2\alpha}$ (mm)	11.5±0.6	10.2±0.5	0.12
Maximal size of the largest ovulatory follicle (mm)	14.6±0.5	14.2±0.4	0.57
Growth rate of the largest ovulatory follicle after $PGF_{2\alpha}$ (mm/d)	0.9±0.1	1.1±0.1	0.17
Interval from $PGF_{2\alpha}$ treatment to ovulation (h)	83.6±5.1	88.0±6.9	0.63

There was a positive correlation coefficient between the time of emergence of the follicular wave and time of ovulation ($r = 0.45$; $P < 0.05$) and a negative correlation coefficient between size of the largest ovulatory follicle at $PGF_{2\alpha}$ and the growth rate of the largest ovulatory follicle after luteolysis ($r = -0.43$; $P < 0.05$).

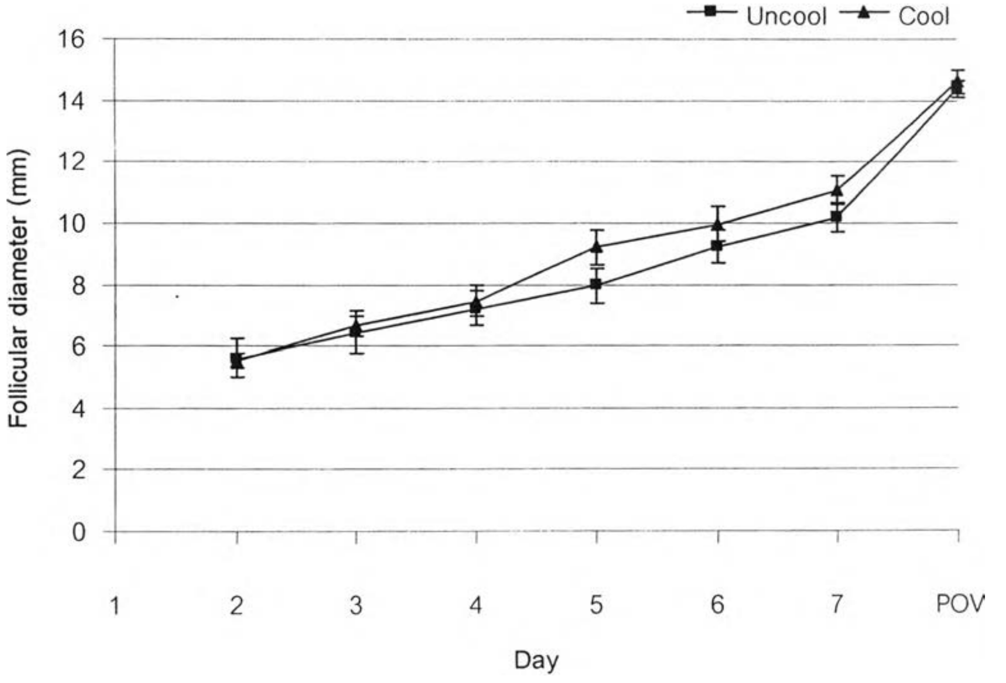

Figure 12. The average diameter of the largest ovulatory follicle for cooled and uncooled cows after synchronization for follicular development.

Conception rate and early embryonic loss

Although TAI programs eliminate any failure to detect oestrus, as a reason for reproductive inefficiency under heat stress, the pregnancy rate is not enhanced.

The percentage of cows in this study that became pregnant was higher($P=0.218$) for the cooled than the uncooled cows 22 d postinsemination when based on plasma progesterone (43.8 and 23.5%, respectively). However, the advantage in conception rate was lost due to increased later embryonic mortality. The conception rate based on ultrasonography on Days 28, 35, and 42 did not differ ($P=0.606$) between the two groups of cows, but the pregnancy rate in the cooled cows was higher than in the uncooled cows.(Figure 13) The percentage of embryonic loss that occurred before Day 18 in the uncooled cows was higher (P=0.218) than in the cooled cows, but an increased rate of embryonic loss occurred between Days 18 and 28 in the cooled cows. (Table 9)

Table 9. The conception rate and embryonic loss after the synchronization of ovulation and fixed time AI of dairy cows in the experimental housing.

Conception rate (%)			Embryonic loss (%)		
Day	Cooled (n)	Uncooled (n)	Day	Cooled (n)	Uncooled (n)
22	43.8 (7/16)	23.5 (4/17)	Before 18	56.2 (9/16)	76.5 (13/17)
28	25.0 (4/16)	17.7 (3/17)	18-28	42.9 (3/7)	25.0 (1/4)
35	25.0 (4/16)	17.7 (3/17)	28-35	0	0
42	25.0 (4/16)	17.7 (3/17)	35-42	0	0
45-60	25.0 (4/16)	17.7 (3/17)	>42	0	0

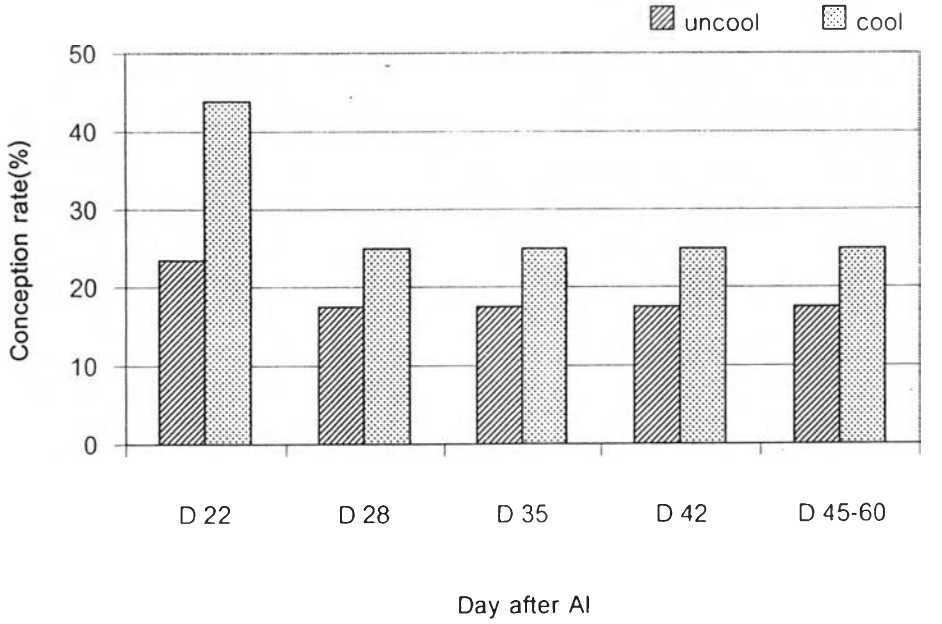

Figure 13. The conception rate after the synchronization of ovulation and fixed time AI of cooled and uncooled cows.

Economic analysis

There are questions that arise regarding the cost effectiveness of an evaporative cooling system over a period of years. In the present study, an economic analysis of the evaporative cooling system showed that cows in the tunnel ventilation barn produced 5.1 kg/cow/day more than the cows housed outside. The milk price was 11.50 baht/kg. Therefore, the use of tunnel ventilation cooling increased revenue by 58.65 baht/cow/day and increased feed costs by 22.17 baht/cow/day. Thus, income over feed cost was 36.48 baht/cow/day.

The cost of the fan and water pump operation was 6.88 baht/cow/day. The total equipment and supply cost to build the tunnel barn facility was 125,000 baht, which, when depreciated over the expected life of the equipment (including maintenance costs of 25,000 baht over 5 years), was 4.11 baht/cow/day.

Thus, the cows housed in the tunnel barn earned 25.49 baht/day or 3823.50 baht more than the cows housed outside over the 22-week study(Table 10).

Table 10. The economic analysis of the evaporative cooling system over the first 22 week of lactation in dairy cows.

Item	Difference	Income-Cost (Baht/cow/day)
Milk yield (kg/cow/day)	5.1	58.65
DMI (kg/cow/day)	2.9	-22.17
Electric cost (fan & water pump operation)		-6.88
Equipment and maintenance cost (5 years)		-4.11
Total		25.49