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Productive and Reproductive Response of Holstein and Brown Swiss Heat Stressed Dairy Cows to Two Different Cooling Systems

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Abstract: Thirty-seven Holstein and 26 Brown Swiss dairy cows were allotted to three treatments to evaluate the effects of two cooling systems on their productive and reproductive response. The treatment control had access to only shade (C). A second treatment was under a spray and fan cooling system (S/F) and the third treatment was cooled with a evaporative cooling system Korral Kool® (KK). The maximum temperature-humidity index recorded was from 73 to 85. Milk production of Holstein cows in S/F (39.1 kg/d) and KK (37.9 kg/d) groups was increased ($P<.05$) compared to C (31.0 kg/d). No treatment differences in milk production were observed in Brown Swiss cows ($P>.05$). Protein percentage in milk was higher ($P<.05$) in C (3.3%) and S/F (3.3%) groups compared to KK (3.1%) in Brown Swiss cows. Fat percentage in milk was increased by both cooling systems in Brown Swiss cows. Pregnancy rate in Holstein cows was improved ($P<.05$) in the groups under the cooling systems 75% (S/F) 58.3% (KK) compared to 0% in C group, however this effect was not observed in Brown Swiss cows where control group had a significantly ($P<.05$) higher pregnancy rate than S/F group. These results demonstrate that both cooling systems are an effective microclimatic modifications to increase productive and reproductive performance of Holstein cows during summer in hot-dry climates. Conversely, Brown Swiss cows were better adapted to heat stress and did not benefit from either cooling system.

Key words: Cooling, Cow, Stress, Milk, Reproduction

Introduction

Studies with dairy cattle report reductions in milk production of 10 to 25% during the summer months (Schneider *et al.*, 1984 and Thatcher *et al.*, 1974). Holstein, Jersey (Ragsdale *et al.*, 1949) and Brown Swiss cows (Ragsdale *et al.*, 1951) have reduced milk production under heat stress conditions. However, reports of breed comparisons among lactating animals have s hown that Jersey cows are less sensitive to hot conditions than Holstein (Harris *et al.*, 1960). In one study under conditions of 34°C and 46% relative humidity, milk production for Holstein, Jersey and Brown Swiss cows was 63, 68 and 84% of that at 24°C and 38% relative humidity (Ragsdale *et al.*, 1953). Legates *et al.* (1991) reported that the order of decreasing thermotolerance to hot conditions was Jersey, Guernsey, Ayrshire and Holstein, both in field and climatic chamber conditions. Milk production was affected by climate more than milk composition in Holstein cows, but in Jersey cows milk composition appeared more sensitive than in Holstein (Sharma *et al.*, 1983). A study conducted by Rodriguez *et al.* (1985) reported a reduction in milk fat and protein percentages in Holstein cows as the temperature rose from 8 to 36°C.

Extremely hot environments disrupt homeostasis and can indirectly alter reproductive function and reduce fertility (Gwazdauskas, 1985). An increase in days open was reported in Holstein cows compared to 1/2 Holstein - 1/2 Brown Swiss or 5/8 Holstein - 1/4 Brown Swiss - 1/8 Jersey during the warm season in four herds in the southeastern United States (Ruvuna *et al.*, 1983).

Environmental modifications have been recommended to reduce heat stress, including water sprays and fans (Armstrong *et al.*, 1988) and evaporative cooling (Ryan *et al.*, 1992) under shades. An economic analysis conducted by Daugherty (1993) showed that spray and fan and evaporative cooling (Korral Kool®) were profitable investments with an increase in milk of 2.6 kg (S/F) and 4.5 kg (KK) in low producing cows under moderate heat stress. Research is needed to evaluate the response to cooling systems of breeds more heat tolerant than Holstein. Therefore, this experiment was conducted to evaluate the effects of two different cooling systems on productive and reproductive responses of lactating Holstein and Brown Swiss cows under heat stress conditions.

Materials and Methods

Experimental Design: Thirty seven Holstein and twenty six Brown Swiss cows were assigned to three treatments according to days in milk and lactation number. Treatments were: The control group with only shade (C). A second group was kept under a spray and fan cooling system (S/F) and the third group was cooled with an evaporative cooling system known as Korral Kool® (KK).

Housing and Cooling Systems: Open dry lot corrals (50 m^2/cow) with shades (4.3 m^2/cow) in the center of each pen were used to kept the animals during the experiment. The shade was made of corrugated steel with a height of 3.9

m. Cows had free access to drinking water in the corral as well as in the holding pen and all the cows were cooled before milking in the holding pen twice daily, with 2 fans (0.9 m diameter with a motor of 1 hp) mounted overhead, which blew air downward at an angle of 30°.

The spray and fans treatment consisted of 6 fans with 0.5 hp and 0.9 m diameter (6 cows/fan) installed on the west side of each pen under the shade at a distance of 3.2 m apart and were tilted 30° downward. The fans produced 180 m^3 of air movement and eight plastic spray nozzles per fan released 0.84 l/min of water. A short curtain (0.9 m length) was installed behind the fans to reduce the impact of external air currents on the efficiency of the cooling system.

Three units (13 cows/unit) of Korral Kool system were spaced at 6 m intervals. This cooling system injects a fine mist generated at high water pressure (1.3-6.4 l/min) into a stream of air blown directly downward from above (760 m^3/min). A curtain 2.5 m in length installed on the west side of the shade. The cooling systems started when ambient temperatures reached 27°C and operated an average of 11h/d (from 0900 h to 1600 h and from 1730 h to 2130 h). Because the cows were fed from 1600 h to 1730 cooling systems were turned off during that period of time.

Feeding: Cows were fed with a total mixed ration (TMR) twice daily (0500 h and 1600 h) formulated for high producing cows. The ration was mixed daily and modified three times during the trial according to milk production and body condition scores of the cows. Nutrient composition of the rations are shown in Table 1.

Climatological Data: Weather information as ambient temperature and relative humidity was recorded hourly during the trial at the Arizona Meteorological Network (AZMET) weather station located 1.5 km from the experimental site. Temperature-humidity index (THI) was calculated by the equation THI = Td - (0.55 - 0.55 X RH) (td - 58)
where td = dry bulb temperature (°F) and RH = relative humidity percentage in decimals (West, 1995).

Performance Measurements: Cows were milked twice daily (0530 h and 1730 h) and milk production was recorded for each cow by a computerized system and 4% fat corrected milk (4% FCM) was estimated. Milk composition was analyzed every two weeks for protein and fat in the Dairy Herd Improvement Association laboratory in Phoenix, Arizona.

Statistical Analysis: Milk production, 4% FCM, milk composition and body condition score were adjusted by covariance for days in milk and milk yield pre-treatment (weeks 1-3) and analyzed by a mixed model with repeated measures, using the procedure of SAS (1989). The model included as fixed effects: treatment, breed, week and lactation number. The random effects were the interaction treatment by lactation nested within cow and the residual. The pregnancy rate was analyzed by chi-square.

Results and Discussions

Climatological Data: Average maximum and minimum THI recorded during the eighteen weeks of the experiment are in Table 2.

Milk Production: Mean milk production of Holstein and Brown Swiss cows by treatment for the entire trial is presented in Table 3. For Holstein cows milk production was 6.9 kg/d greater (P<.05) for KK and 8.1 kg/d higher (P<.05) for S/F than C group. No difference was noted between S/F and KK cows (P>.05). Brown Swiss cows did not show any milk production response to cooling systems. An interaction was detected for treatment by week (P<.01) in Holstein (Fig. 1) and Brown Swiss cows (Fig. 2; P<.05), which reflected higher milk production for the cooled groups during the hottest weeks. Milk production adjusted to 4% fat (FCM) was affected by cooling treatment (P<.05) in Holstein cows (Table 3), but not in Brown Swiss cows (P>.05).

Milk Composition: Milk protein percentages for Holstein and Brown Swiss cows are presented in Table 3. Holstein cows averaged lower protein percentage in the groups under cooling systems compared to control group although these differences were not significant (P>.05). Milk protein percentage in Brown Swiss was similar (P>.05) among C and S/F and both were greater (P<.05) than the KK group. Similar fat percentages (P>.05) were observed among treatments for Holstein cows; however Brown Swiss cows had a higher fat percentage in the cooled groups (P<.05). The treatment by week interaction on fat percentage was significant (P<.01) for Holstein cows (Fig. 3). Differences between treatments in fat percentages were observed only during weeks 8 and 12 (P<.05). No treatment by week interaction (P>.05) was detected for Brown Swiss cows.

Reproductive Performance: Data summarizing effects of cooling system on reproductive efficiency are presented in Table 4. Pregnancy rate in Holstein cows was increased (P<.05) by cooling (75% for S/F, 58.3% for KK and 0% for C). For control Brown Swiss cows pregnancy rate (66.6%) was higher (P<.05) than S/F (25%) but not different from

KK (55.5%). No differences between treatments were found for services per conception and days open (p>.05) which may be related to the small number of pregnant cows in each treatment.

Climatological Data: The range of maximum THI during this trial was from 73 to 85 while, the minimum THI range was 56 to 74. A THI of 72 is considered as an value at which heat stress affects milk production (Johnson, 1980). The maximum THI recorded during the day was superior to 72 indicating a heat stress from mild to moderate affecting negatively on milk yield (Armstrong, 1994). A reduction in ITH to less than 64 for at least 6 hrs. reduces the negative effects of heat stress (Igono *et al.*, 1992).The minimum THI indicated that during the experiment the cows did not have an alleviate of heat stress in the most of the time.

Milk Production: Our results agree with several experiments that reported higher milk production in Holstein cows under spray and fans (Igono *et al.*, 1985; Igono *et al.*, 1987 and Goodwin *et al.*, 1997) and Korral Kool (Armstrong *et al.*, 1985) compared to shade only. Milk production of heat-stressed Brown Swiss cows under various cooling systems has not been reported previously.

Differences between treatments were greatest from weeks 7 to 18 (P<.05), when the average maximum THI was 82. During the last 7 weeks of the trial milk production in KK group tended to decrease compared to S/F, which was opposite to effects observed during the beginning of the trial. Highest maximum relative humidity was recorded during the last seven weeks of the trial (84% average). The fine mist produced by KK, combined with high relative ambient humidity increased overall humidity of the surrounding air and reduced the animal's capacity to dissipate heat by evaporation, similar to the results reported by Flamenbaum *et al.* (1986). Since amount of water sprayed by S/F was less than KK, the negative effect of high humidity was likely not as apparent with the S/F system. Flamenbaum *et al.* (1995) also observed an increased milk yield (4% FCM) in Holstein cows under cooling systems compared with shade only.

Productivity at high ambient temperatures is greatly influenced by the balance between metabolic heat production and heat loss. Studies indicate the primary reasons for heat tolerance is lower metabolic heat production and reduced milk production (McDowell, 1972). For each .45 kg of milk produced, a 454 kg cow produces 10 kcal of metabolic heat per hour (Brody *et al.*, 1948). The lack of an effect of cooling systems on milk production of Brown Swiss cows may be due to their lower milk production and body weight, thus resulting in less metabolic heat produced and a lower level of heat stress than in Holstein cows.

Resistance of the animal coat to environmental heat-flow is of great importance in tolerance to heat stress. Coat color also affects heat exchange. Compared to black color, brown color reduces the inward flow of heat 16% while white color reduces it 58% (Finch, 1986). Brown Swiss cows might have benefited from their lighter color as compared to most of the Holstein cows.

Johnson and Vanjonack, (1976) reported that Holstein cows showed a greater sensitivity to heat stress than Brown Swiss. A study conducted at the University of Arizona showed that Holstein cows absorb about 89% of direct solar heat while Brown Swiss absorb about 81%. Also, Brown Swiss had higher rates of cutaneous evaporation than Holsteins, resulting in a lower skin temperature (Armstrong and Hillman, 1998). These differences may explain the greater heat tolerance of Brown Swiss than Holsteins since evaporative cooling is the major avenue of heat loss in cattle under hot, arid conditions.

Milk Composition: These findings are in agreement with Smith *et al.* (1993) who did not find differences for protein percentages in milk of Holstein cows under a spray and fan system compared to only shade. On the other hand they differ with Strickland *et al.* (1989) who found higher protein percentages in milk of Holstein cows in a hot-humid climate cooled with a sprinkler and fan system compared to shade only. Flamenbaum *et al.* (1995) also reported a .06% higher protein percentage in Holstein cows cooled with the Korral Kool system compared to shade only.

Some authors have observed that fatty acids of a lower melting point (C_6 - C_{12}, oleic acid) decreased at higher ambient temperatures and free fatty acids (palmitic, stearic and myristic) of higher melting points increased (Richardson and Johnson, 1961). The lack of differences in fat percentages between treatments in Holstein cows agree with the results of other studies using sprinkler and fan (Strickland *et al.* 1989), spray and fan (Smith *et al.*, 1993) or Korral Kool systems (Flamenbaum *et al.*, 1995).

Shearer and Beede, (1990) suggested that heat stress is associated with changes in milk composition, which may be due to a reduction in feed intake. Because feed consumption could not be evaluated in the present study, the importance of this factor could not be determined.

Table 1: Nutrient composition of the rations[1]

Item[2]	Ration 1	Ration 2	Ration 3
Mcal/kg DM	01.70	01.7	01.7
Fat, %	04.12	03.7	03.8
Crude protein, %	18.90	17.6	17.8
UIP[3], % of crude protein	29.90	30.6	29.4
NDF[4], %	29.10	30.3	29.5
ADF[5], %	20.20	20.2	20.3
Ca, %	01.00	01.0	01.0
P, %	00.50	00.5	00.5
Mg, %	00.30	00.3	00.3
K, %	01.70	01.7	01.7
Cl, %	01.00	01.0	01.0
Na, %	00.50	00.5	00.5

[1]Ration 1 = Offered from May 30 to July 12; Ration 2 = Offered from July 13 to August 19; Ration 3 = Offered from August 20 to the end of the experiment.
[2]All items except Mcal and UIP are given as percent of DM in the total diet.
[3]Undegradable intake protein.
[4]Neutral detergent fiber.
[5]Acid detergent fiber.

Table 2: Weekly averages of maximum and minimum temperature-humidity index (THI) during the trial

Week	Maximum THI	Minimum THI
1	79	59
2	77	60
3	73	56
4	79	59
5	80	66
6	80	65
7	79	67
8	82	71
9	83	74
10	82	72
11	83	73
12	80	72
13	82	71
14	81	71
15	82	72
16	85	68
17	85	67
18	80	62
Average weeks 1-18	81	67
Average weeks 4-18	82	69

Table 3: Effect of cooling systems on milk yield and composition of Holstein and Brown Swiss heat-stressed dairy cows[1]

		Holstein			Brown Swiss	
Item	Control	Spray/fan	Korral Kool	Control	Spray/fan	Korral Kool
Milk production(kg/d)	31.0 ^{a} ± 1.6	39.1 ^{b} ± 1.4	37.9 ^{b} ± 1.3	29.8 ^{a} ± 1.0	31.3 ^{a} ± 0.9	31.4 ^{a} ± 1.0
FCM 4%, kg/d	28.5 ^{a} ± 1.2	32.5 ^{b} ± 1.0	32.9 ^{b} ± 1.0	27.3 ^{a} ± 1.0	29.1 ^{a} ± 0.9	28.9 ^{a} ± 1.0
Milk protein, %	3.0 ^{a} ± 0.06	2.8 ^{a} ± 0.06	2.9 ^{a} ± 0.04	3.3 ^{a} ± 0.09	3.3 ^{a} ± 0.09	3.1 ^{b} ± 0.08
Milk fat, %	3.0 ^{a} ± 0.11	2.9 ^{a} ± 0.14	2.9 ^{a} ± 0.06	3.3 ^{a} ± 0.08	3.7 ^{b} ± 0.10	3.5 ^{ab} ± 0.10

[1] Data presented are least square means ± standard error.
[a,b] Means within a row with different superscript are different (P<.05).

Table 4: Effect of cooling systems on pregnancy rate of Holstein and Brown Swiss heat-stressed dairy cows

	Pregnancy rate (%)	
Treatment	Holstein	Brown swiss
Control	0.0[a] (0/11)	66.6[a] (4/6)
Spray and fans	75.0[b] (9/12)	25.0[b] (2/8)
Korral Kool	5 8.3[b] (7/12)	55.5[a] (5/9)

[a, b] Means with different superscript within column are different (P<.05).
[*] Number in parentheses indicates the proportion of pregnant cows.

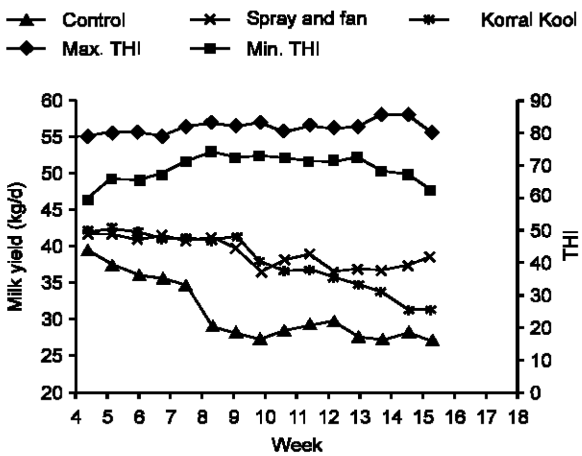

Fig. 1: Effect of cooling systems and temperature-humidity index on milk yield of heat-stressed holstien cows

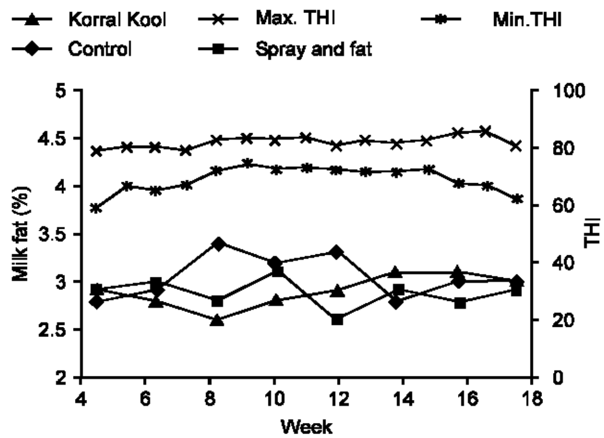

Fig. 2: Effect of cooling system and temperature-humidity index on milk yield of heat-stressed Brown Swiss cows

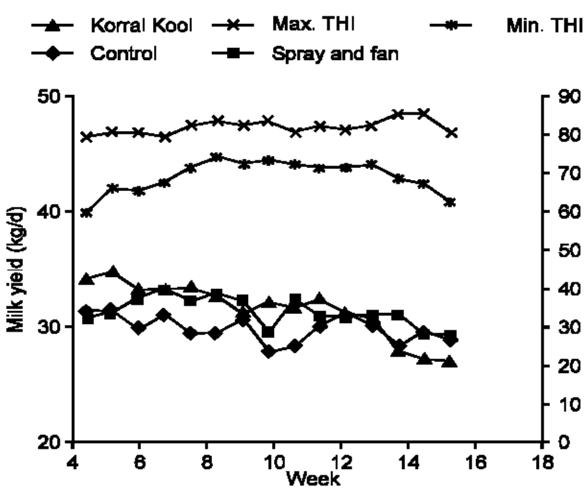

Fig. 3: Effect of cooling system and temperature-humidity index on percentage in milk of heat-stressed Holstein cows

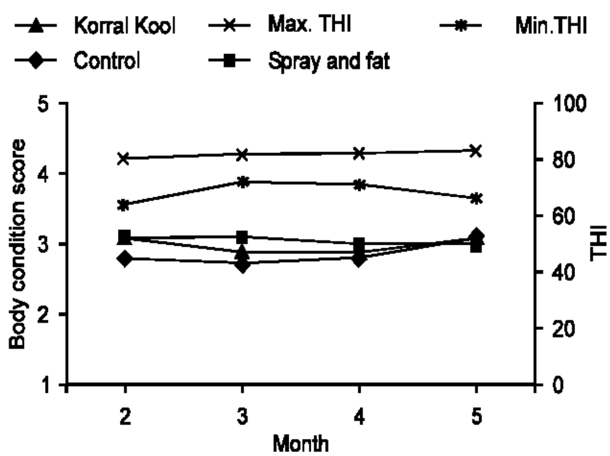

Fig. 4: Effect of cooling systems and temperature-humidity index on body condition score of heat-stressed Brown Swiss cows

Reproductive Performance: This study shows the benefit of both cooling systems on pregnancy rate of Holstein cows and agree with several experiments as Ryan *et al.* (1992) who found that 84% of cows with Korral Kool and 60% under a spray and fan system became pregnant. Wolfenson *et al.* (1988) reported a higher pregnancy rate in cooled (44%) than in non-cooled Holstein cows (14%) during the summer. However, Brown Swiss cows had a better pregnancy rate in the control group compared to cooling systems showing no benefit of the cooling systems. A similar effect was observed on milk production. The same characteristics of the Brown Swiss cows of resistance to heat stress discussed on milk production results could have determined the best reproductive performance in the group with only shade. Ruvuna *et al.* (1983) reported that Brown Swiss cows appeared to be affected less adversely by hot weather

and consequently better reproductive parameters compared to Holsteins. Although Brown Swiss cows had lower milk production in response to cooling, their milk yield was similar to Holstein in the control group with a reproductive performance superior to Holstein which is a great advantage in hot climates.
A Physiological and hormonal response measured as rectal temperature, respiration rate, level of T_3 and T_4 for this study were reported previously (Correa *et al.*, 2004). These data also indicated an improvement in the comfort for Holstein and Brown Swiss cows in response to the cooling systems.

Conclusion

The results of this experiment indicate benefits of both cooling systems on milk yield of Holstein cows under a moderate heat stress. A higher milk yield response to the cooling systems is expected in areas characterized by a heat stress more severe than in the present study. Based on these results the use of spray and fans cooling system would be recommended for Holstein cows due to its lower investment, however additional research is suggested. A decision to recommend a cooling system for hot climates must be based on breed, degree of heat stress in the area and an economic analysis.

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This research comply with current United States of America Laws.

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