ALLEVIATION OF HEAT STRESS FOR HOLSTEIN LACTATING COWS IN HOT SUMMER BY A WET-PADDING BARN

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ABSTRACT

Heat stress resulted from high temperature (T) and relative humidity (RH) is an obstacle that limits the development of livestock industry in Taiwan. Feasibility of using a wet-padding (WP) barn to alleviate heat stress for Holstein lactating cows was assessed. Cows fed in the conventional (C) free stall barn were designated to be control group. Eight exhaust fans set at one end of WP barn drew the air through water padding at the other barn end and cooled the barn T. Maximum air exchange velocity achieved twice per minute. There were four fans and time-set sprinkling to cool the C barn. In hot summer of 2005, average daily T inside WP and C barns were 26.6℃ and 27.8℃, and RH were 97.6% and 88.5%, respectively. Cow responses and performance raised in these two barns were studied in a crossover design with 30 days a period and a total of 42 lactating cows. Results indicated that WP environment increased heat load of cows. Respiration rate at 4 a.m. (62.2 vs. 49.8 times per min, $P < .001$), rectal T at 4 a.m. (39.58 vs. 39.31℃, $P < .01$) and 2 p.m. (39.75 vs. 39.47℃, $P < .03$) were all increased. Moreover, WP barn lowered the dry matter intake by 7.6% (17.0 vs. 18.4 kg), milk yield by 9.3% (23.3 vs. 25.7 kg, $P < .001$), milk protein percentage (3.27 vs. 3.33%, $P < .05$), milk total solid percentage, and intake activity after p.m. feed was offered (35.7 vs. 62.1%, $P < .05$). Although WP barn could decrease T more efficient than C barn, persistently high RH (≥ 93.5%) might restrict heat release by way of surface skin and thus cause the higher body T and lower performance. More WP design studies focusing on decreasing RH is necessary.

KEY WORDS: Environmental parameters, Heat stress, Holstein lactating cows, Milking performance, Physiological response, Wet-padding barn.

INTRODUCTION

Comfort zone for Holstein cattle range from -0.5 to 20℃. The highest critical temperature (T) was around 25 to 26℃ (Berman *et al*., 1985). When T comes above 26.7℃, intake starts to decrease. There are eight months (from April to Nov.) having the highest T above 26.7℃ and average RH 78% in the southern Taiwan. Heat stress results in decreased intake, decreased milk yield and almost zero conception rates. A wet-padding (WP) barn forces air going through wet-padding and cools the barn. It has been successfully applied in chicken and

swine breeders. Only limit research was conducted for dairy. It was aimed to assess the feasibility whether WP barn could alleviate heat stress for lactating cows in Taiwan.

MATERIALS AND METHODS

Barns and Environmental Parameters

The WP barn is a 50 m long one-row free stall barn with flat ceiling height of 2.5 m. Eight exhaust fans with one HP, 48" diameter, six vanes and 32,000 m^3/hr air flow volume were set at one end of the barn. Two three-layer and nest-shape plastic wet-paddings with total volume of 13.0*1.8*0.45 m^3 (L*H*D) were built up at the other end. Air flow volume was controlled by computer program. Three fans operated when barn T was lower than 26℃. Once barn T was higher than 26℃, pump for water circulation on padding would be started and numbers of fans operating would linearly increase to maximum seven. A conventional (C) barn is also a free stall design with rooftop of 11.8 m and eaves of 3.4 m in height. Four fans with 2 HP, 36" diameter, three vanes and 26,300 m^3/hr air flow volume were continuously operated. Sprinkle cooling was applied at 5:30, 6:30, 10:30, 15:50, 16:50 and 17:50 for 30 minutes each to stimulate intake. Six cycles with 1-minute water spraying and 4-minute blowing were executed. Electricity meters were recorded daily in two barns for power consumption from fan, light and water pump. Air flow velocity in WP barn was measured with fully operated fans. HOBO Pro RH/Temp sensors were evenly hanged inside WP barn (n = 8) and C barn (n = 3) to measure RH and T every 30 min. Data were weekly transferred into computer for 48 days. The temperature-humidity index (NOAA, 1976) was also calculated.

Cow Responses and Performance

A crossover design with 30-d each period was conducted with 42 head of Holstein lactating cows to measure their responses and performance when raised in WP and C barn. Cows with initial milk yield of 26.2 ± 5.5 kg were group-fed on same diet. Daily water consumption was measured. Individual respiration rates and rectal T were measured at cool 4 a.m. and hot 2 p.m. in one day and repeated twice. Body weight changes, daily group intake, and individual milk yield were recorded. Three a.m. and p.m. milk samples were taken for composition analyses. Rumen samples were taken every 1.5 to 3 hrs after a.m. feeding two days to measure the diurnal pH changes. Intake activity was monitored three days to calculate intake activity every 10 min (intake head/total head*100%). Differences in cows' responses and performance between WP and C barns were statistically analyzed by the general linear model of SAS (1999-2000). Significant level was set at 5%.

RESULTS AND DISCUSSION

Environmental Parameters in WP and C Barns

Electricity consumption in WP barn was 2.7 folds higher than that in C barn, i.e. 7.71 and 2.82 wh/au (1 animal unit = 1,000 lb body wt.). With seven fans, air flow velocity in WP barn was 1.66 m/sec that indicated maximum air exchanges rate could achieve twice per minute.

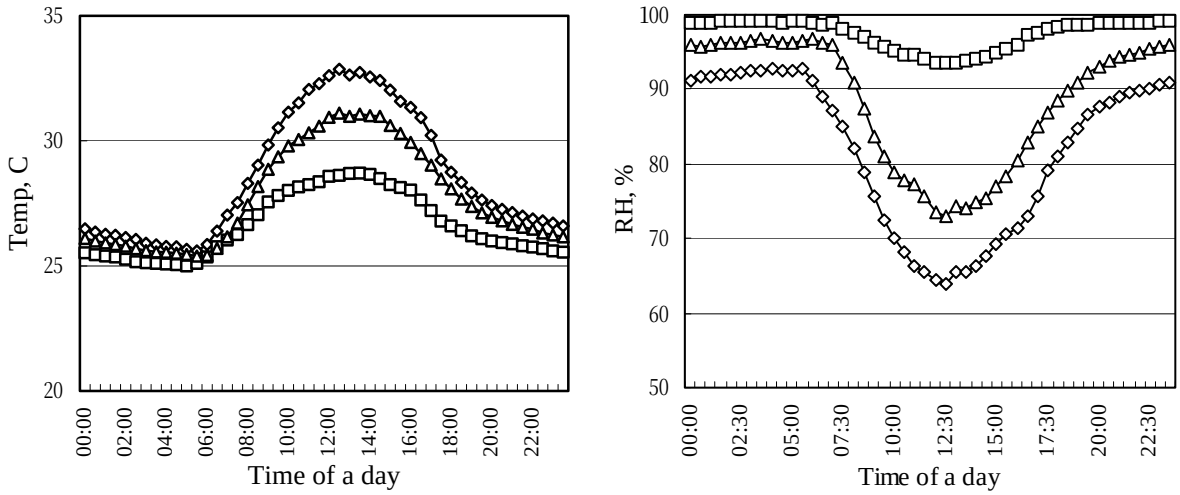

Fig. 1. Diurnal temperature (left) and relative humidity (right) changes of ambient (◇), conventional barn (△), and wet-padding barn (□) during hot summer in 2005.

Diurnal T changes revealed that WP had better cooling efficiency than C barn (Fig. 1, left). Following the increasing T, RH in C barn decreased to 73% (Fig. 1, right). However RH inside WP barn was persistently higher than 93%. THI was reported as a climate index for livestock (LCI, 1970). THI ≤ 74, 75 – 78, 79 – 83 and ≥ 84 represented comfort, warning, dangerous and emergent condition, respectively. THI from both barns were all above 74 and ranged from 77 to 84 that indicated cows were all suffered medium to high stress.

Cows' Responses and Performance

Cows drank more water in WP barn, water consumptions were 64.2 and 49.5 L/au. WP environment increased heat load of cows (Table 1). Respiration rate at cool 4 a.m. had already elevated by 25%. Rectal T at cool morning and hot afternoon were also significantly higher. Milking performance was adversely affected by WP environment (Table 2). It decreased 7.6% of cows' DM intake, i.e. 1.4 kg per day per cow. The 4% fat-corrected milk yield, milk protein percentage, and milk total solids percentage were significantly lowered by 9.3%, 1.8%, and 1.5%, respectively. Owing to the significant lowered milk yield, yield of milk compositions in terms of milk fat, protein, lactose and total solids were all decreased ($P < .001$). Ruminal pH changes were similar in two groups with diurnal average of 6.09. Cows would increase their intake activity after fresh diet is offered. When analyzed by time segment, WP environment mainly decreased the intake activity ($P < 0.05$) after p.m. feed offered 2 hrs (35.7% vs. 62.1%).

Table 1. Effects of wet-padding environment on respiration rates (RR) and rectal temperature (RT) of Holstein lactating cows in hot summer

Items	Wet-padding barn	Conventional barn	Significance [1]
4 a.m. RR, times/min	62.2	49.8	***
2 p.m. RR, times/min	70.9	72.4	NS
4 a.m. RT, ℃	39.58	39.31	**
2 p.m. RT, ℃	39.75	39.47	*

[1] NS: not significant, *: $P < 0.05$, **: $P < 0.01$, ***: $P < 0.001$.

Table 2. Effects of WP environment on milking performance of Holstein lactating cows in hot summer

Items	Wet-padding barn	Conventional barn	Significance[1]
Daily body wt. gain, kg	0.083	-0.004	NS
DM intake, kg/day	17.0	18.4	NS
4% FCM, kg/day	23.1	25.7	***
Milk fat, %	3.93	4.02	NS
Milk protein, %	3.27	3.33	*
Milk lactose, %	4.75	4.79	NS
Milk total solids, %	12.57	12.76	**

[1] Footnote as Table 1.

Persistently high RH is highly detrimental to lactating cows. It might restrict the heat evaporation function from cows' skin surface. Increased heat load resulted in decreased performance. It was suggested that the twice per minute air exchanges rate was not high enough to take away its high humidity. More WP design studies were necessary.

REFERENCE

Berman, A., Y. Folman, M. Kaim, M. Mamen, Z. Herz, D. Wolfenson, A. Arieli and Y. Graber. 1985. Upper critical temperature and forced ventilation effects for high-yielding dairy cattle in a subtropical climate. J. Dairy Sci. 68:1488-1495.

LCI. 1970. Patterns of transit losses. Livestock Conservation, Inc., Omaha, NE.

National Oceanic and Atmospheric Administration. 1976. Livestock hot weather stress. U. S. Dept. of Commerce, NOAA, Natl. Weather Service Central Region. Regional Operations Manual Letter C-31-76.