Effects of Localized Air Flowing System in Free Stalls on Behavior of Lactating Cows in a Hot Environment

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Abstract

The influence of continuous localized air flows from a pipe mounted 110 cm above the front edge of stall floors on cow behavior in a hot environment was studied by using seven lactating Holstein cows kept in free stall (FS) housing. The localized air flowing system is characterized as a mechanism which sends air over a cow's body in a stall, from blast holes in a vinyl chloride tube set on the neck rail bar of the stalls. Three behavioral observations were made during each three-day period between July 18 and August 3, '99: Period 1 with localized air flows in the rainy season; Period 2 with localized air flows after the rainy season; and Period 3 with no localized air flows after the rainy season. Air temperature in Periods 1, 2, and 3 averaged 22.6℃, 26.3℃, and 26.8℃, respectively. Period 3 with no air flow resulted in significantly ($P< .05$) lower milk yields and body weights, but with a non-significant trend toward lower dry matter intake. The daily lying time, total use time of the stalls, and eating time were significantly ($P< .05$) longer in the order of Period 1, Period 2, Period 3, whereas daily standing and migrating time in the alleys was significantly ($P< .05$) longer in the reverse order. Based on these observations, we concluded that localized air flows results in a higher stall use and longer eating time.

Key words: Localized air flow, Free stall, Lying behavior, Lactating cows, Hot environment

Introduction

Thermo-regulative behavior such as decreased lying time[2,5,8,11,13] in stalls and/or increased standing time, the higher rate of recumbent cows in the cooler alleys than in stalls, and decreases in feed intake and milk production are observed in milking cows kept in free stall (FS) barns during the summer in hot climates.

The decrease in the temperature inclination of the animal surface by the rise in floor temperatures during lying and the smaller body surface area for heat loss through evaporation and convection during lying seem to result in decreases in lying time as a reaction designed to increase the amount of heat radiation[4]. This thermo-regulative behavior increases the stress due to shorter lying time and the energy consumption resulting from standing.

In general FS housing, mechanical ventilation with large mixing fans suspended from the ceiling are used to force air to sending floors in order to decrease heat stress and to dry wet floors. However, cattle will stay longer in the cooler alleys than stalls in summer, if the fans are installed only above the alleys. Therefore, large mixing fans might not necessarily provide greater control over the drying of wet floors and the occurrences of hoof diseases.

If the microclimate of free stalls in summer could be controlled adequately, cows will rest in the stalls rather than in the alleys, and decreases in feed intake and milk production from heat stress will be reduced. Therefore, a system for localized air flow was developed to force air to cows in the stalls (Patent pending No.2001-23661). The effects of localized air flow were studied on behavior and milk production in lactating cows in FS housing in a hot environment.

Materials and Methods

Seven lactating Holstein cows were kept in a FS barn of the former National Grassland Research

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Institute (Tochigi-ken). Their ages at the start of the observation averaged 69 ± 30 (Sd) months, body weight 655 ± 65 kg, daily milk yields 33.1 ± 7.2 kg, and days after calvings 88 ± 93 (Table 1).

The FS area observed had an area of 113 m^2 with 8 feed troughs, 2 waterers and 8 stalls (Fig. 1), which was part of the FS housing of 222 m^2, equipped with 16 stalls in two head to head rows.

Each stall consisted of Michigan-type partitions, a neck rail, a brisket board, and a curb for stopping bedding materials. The FS size for the cow's body space was 120 × 168 cm per cow with a 6% slope and 25 cm above the alleys. The feed and stall alley was 3.7 m wide. The bedding base consisted of a molded rubber chip mattress compacted to 3.2 cm and covered with polyester cloths.

Table 1. Cow characteristics at the first day (7/18/'99) of observations.

Cow No.	Age (mo)	BW (kg)[a]	MY(kg)[b]	Days after calvings
4	111	623	40.8	26
8	99	680	24.3	118
13	74	786	26.5	125
16	46	639	36.9	50
19	43	601	34.3	124
20	43	602	35.6	85
25	38	629	21.9	312
Average	69	655	33.1	88
Sd	30	65	7.2	93

Note: [a]Body weight [b]Daily milk yield

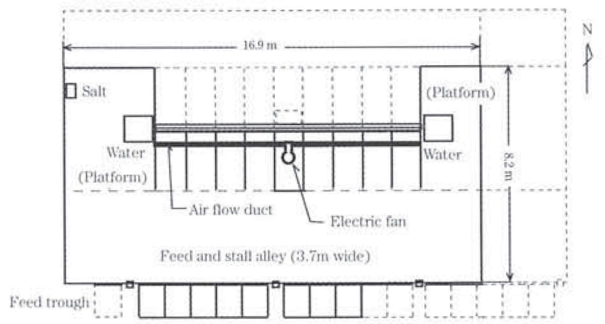

Fig. 1. Overhead view of free stall pen in which observed herd was kept.

The localized air flow period was from July 14 to 28, '99 and the no-air flow period was from July 29 to August 3, '99. Three behavioral observations were made for each 3 day periods: Period 1 with localized air flow during the rainy season; Period 2 with localized air flow after the rainy season; and Period 3 with no localized air flow after the rainy season (Table 2). The air temperatures tended to be higher with the lapse of time. Estrous cows were not found during the three Periods.

Continuous 24-hour air flow (rpm of electric flowers was always constant) was utilized during Periods 1 and 2 for cows in the stalls (lying, standing and putting their forelegs in the stalls). The 7.5 cm diameter hard vinyl chloride blast pipe was installed on the neck rail bar at 110 cm above the front edge of the FS floors (Photo 1, Fig. 2). Blast holes 1cm in diameter (12-13 holes per stall 120 cm wide) were opened in the blast pipe. The wind velocity was 10-11 m/sec. at the outlet, 1.5-1.7 m/sec. around 60 cm from the blast holes (around the shoulders when cows lie down) and 0.2-0.3 m/sec. on the stall floors.

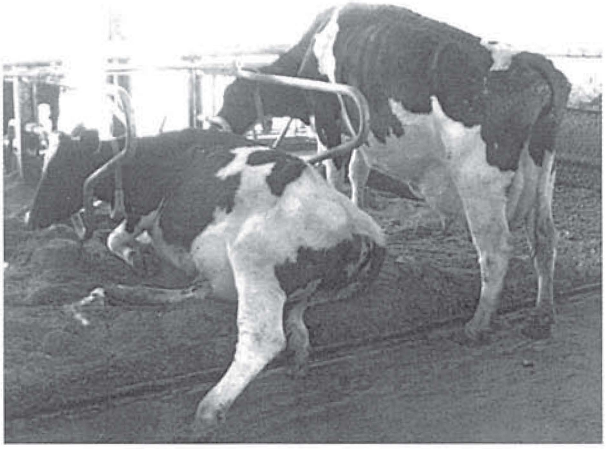

Photo 1. Cows utilizing stalls with localized air flowing system.

Table 2. Experimental design.

	July '99																	August			
Date	14	15	16	17	18	19	20	21	22	23[a]	24	25	26	27	28	29	30	31	1	2	3
	Rainy season																				
Daily avg. air temp.(℃)	23.5	24.3	25.6	24.8	22.3	23.4	22.3	23.8	23.7	25.0	26.0	24.8	27.0	27.2	26.7	26.7	27.3	26.3	27.2	27.0	27.3
Relative humidity (%)	96	94	87	88	91	85	95	93	91	86	82	89	82	81	84	85	80	80	76	76	81
Treatment	Localized air flow															No localized flow					
Observation period[b]				Period 1							Period 2						Period 3				

Note: [a] The end of the rainy season was declared on 23 July.
[b] Three behavioral observations were done: Period 1 with localized air flow during the rainy season.
Period 2 with localized air flow after the rainy season and Period 3 with no localized air flow after the rainy season.

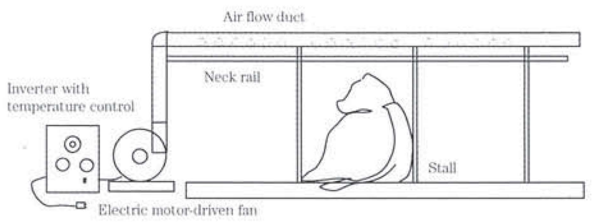

Fig. 2. Equipment for sending air to lying cows in stalls.

Separated manure compost, including sawdust, was evenly spread approximately 0.022 m^3 per stall (approximately 1 cm thick) once a day as bedding material throughout the investigation. Indoor air temperature and relative humidity were measured with a self-registering thermo-humidity meter set up 2.2 m above the center of the FS area.

A total mixed ration (TMR) was dispensed to each feed trough by an automatic continual TMR mixing feeder. The DM ratio was 36% Italian ryegrass silage made in a underground rectangular silo on the same day and from the same field, 43% commercial formula, 10% beet pulp, 10% alfalfa pellets and 1% supplements with 70% TDN and 15% CP. The TMR was fed *ad libitum* (Ratio of residuals to feeding averaged 20.8%) evenly five times a day at 5 : 15, 10 : 15, 13 : 15, 16 : 15, and 19 :15. Every cow could use any of the feed troughs. Drinking water and salt licks were supplied *ad libitum*. Milkings were done twice a day at 8 : 30 a.m. and 18 : 00 p.m., and the excreta in the alleys was taken out with an automatic scraper.

The three periods were observed with two CCD cameras with super-wide-angle lens. The behavior of cows were observed at 1 minute intervals and recorded on a time-lapse video recorder. Each cow was identified by a painted body number on both sides in advance and spot pattern photos.

The behavior observed was classified into eating, standing or migrating, lying, and standing with four legs or with forelegs in the stall, and absent from the barn for milking in the milking parlor, then total time for each daily behavior and the number of behavior bouts were totaled. One behavior bout was defined as a continuous period until shifting to another behavior, but one eating bout was defined as a continuous period at one feed trough. In addition, the travel line of each cow was recorded on a map, and the cow's walking distance was measured with a curvimeter.

Daily dry matter intake (DMI) and daily milk yield during each period and body weight before and after each period were measured to obtain average values for the periods. Respiration rates and rectal temperatures were measured between 14 : 30 and 15 : 00 the following day of each last observation day to prevent a disturbance of behavior observation.

Two factors of periods and cows were subjected to the analysis of variance.

Results

Table 3 shows environmental conditions, cows' performance etc. for the three periods.

The temperatures for each period averaged 22.6 ℃, 26.3 ℃ and 26.8 ℃, respectively, increasing by about 4℃ in Periods 2 and 3 after the end of the rainy season, compared with Period 1. Similarly, the sensible temperatures for these periods averaged 21.9℃, 24.9℃ and 24.8℃, respectively, increasing by 3℃ in Periods 2 and 3. The respiration rate (/min.) averaged 66, 86 and 93 , respectively, increasing obviously in Period 2 and 3 with the hotter environment. The rectal temperatures averaged 39.3 ℃ in Period 1 and increased by about 1 ℃, to 40.1- 40.2 ℃, in Periods 2 and 3.

Table 3. Indoor environmental conditions, DMI, milk yield, and body weight (n=7) in each observation period.

Observation period Treatment		Period 1 Air flow	Period 2 Air flow	Period 3 No air flow	Differences[a)]
Mean air temp.	(℃/day)	22.6	26.3	26.8	—
(Min.-Max.)		(20.5-24.5)	(23.0-30.8)	(23.7-31.2)	
Mean sensible temp.[b)]	(℃/day)	21.9	24.9	24.8	—
Mean relative humidity	(%/day)	90	84	77	—
Respiration rate[c)]	(/min.)	66 [a]	86 [b]	93 [c]	**
Rectal temp.[c)]	(℃)	39.3 [a]	40.1 [b]	40.2 [b]	**
Dry matter intake (DMI)	(kg/day)	19.3	20.7	18.4	NS
Milk yield	(kg/day)	30.5 [a]	30.3 [a]	28.5 [b]	*
Body weight	(kg)	659 [a]	667 [a]	651 [b]	*

Note: [a)] Test with analysis of variance due to two factors of observation periods and cows

NS P>.05 *P<.05 **P<.01

[b)] = 0.35 × Dry bulb temp.+0.65 × Wet bulb temp.

[c)] measured between 14:30 and 15:00 at the next day of each last observation day.

[abc]: Figures without a common letter are statistically different (P<.05).

The daily DMI per cow ranged 18.4-20.7 kg, though it did not change significantly between periods. The daily milk yields ranged 28.5-30.5 kg with significant (P< 0.05) differences between Period 3 and Periods 1 or 2. The live weights ranged between 651-659 kg, decreasing significantly (P< 0.05) in Period 3 with no air flow.

Time budgets and frequency of daily behavior and walking distances for the three periods are shown in Table 4.

In the comparison between Period 1 and Period 2 when localized air flows were operated in the stalls, daily lying time and total use time in the stalls decreased significantly (P< 0.05) by about 13% because of rises in air temperature and sensible temperature, but there were no significant differences in daily lying and total use frequency in the stalls. On the other hand, the daily standing and migrating time in the alleys increased by as much as 40%, from 338 min. to 473 min..

In the comparison between Period 2 and Period 3 after the end of the rainy season, daily lying time on stalls decreases significantly (P< 0.05) by about 12%, from 477 min. to 421 min., and daily total use time in the stalls decreased significantly (P< 0.05) by as much as 15%, from 693min. to 588 min. by stopping localized air flows, whereas, daily standing and migrating time in the alleys increased significantly (P< 0.05) by as much as 27%, from 473 min. to 602 min.

Although there was no significant difference in daily stall lying frequency between Periods 2 and 3, with similar hot environments, daily total stall use frequency decreased significantly (P< 0.05) by 20% in Period 3 with no localized air flows.

Discussion

The upper critical temperature of the thermo-neutral zone (TNZ) for cows is generally within the range of 24-27 ℃ [2] and the rectal temperature in optimum environments averages 38.6 ℃ [1]. The range of mean air temperatures, rectal temperatures and respiration rates during the three periods were higher than or around the upper values of the TNZ, although respiration rates and rectal temperatures measured between 14 : 30 and 15 : 00 are considered to have been higher than the daily average[3]. The environmental conditions for observation periods were within the range where the effect of localized air flows on the alleviation of heat stress was able to be evaluated.

The daily lying time is generally said to be between 8 and 14 hours[9]. In a previous study[5], the daily average lying time in the same FS barn in a TNZ averaged 663 min. An influence of heat stress on lying behavior was identified in the present study, since all of the daily average lying time in the periods were shorter than 663 min. (Table 4), demonstrating that the lying time in hot environments is shorter, not only in grazing cattle[6] and tethered cattle[4], but also in cattle in FS housing[8,13].

For recumbent cows in stalls in the hot environment, air flows from blast holes were aimed at the head, neck or forequarters of the trunk, which are the main areas of high cutaneous moisture vaporization[10] and flowed onto the rear regions of the trunk during lying. Cows standing with four legs or forelegs in the stalls kept their heads in the air flowing zone, which indicates that cows preferred the stall surroundings.

Table 4. Daily behavior of cows (n=7) in each observation period.

Observation period Treatment	Period 1 Air flow	Period 2 Air flow	Period 3 No air flow	Differences[a)]
Time budget min./head/day				
Lying in stall	550 [a]	477 [b]	421 [c]	**
Standing in stall	31 [a]	23 [ab]	20 [b]	NS
Putting forelegs in stall	211 [a]	193 [ab]	146 [b]	*
Total stall use	792 [a]	693 [b]	588 [c]	**
Standing or migrating in alley	338 [a]	473 [b]	602 [c]	**
Eating in alley	247 [a]	208 [b]	199 [b]	**
Absent from the Pen to milking	62 [a]	65 [b]	52 [c]	**
Frequency times/head/day				
Lying in stall	9.4	10.2	8.5	NS
Standing in stall	6.9	7.0	5.5	NS
Putting forelegs in stall	16.0	17.5	13.6	NS
Total stall use	32.3 [ab]	34.8 [a]	27.7 [b]	*
Standing or migrating in alley	22.3	24.2	21.2	NS
Eating in alley[b)]	47.3	47.4	46.4	NS
Absent from the pen to milking	2.0	2.0	2.0	NS
Walking distance m	374 [a]	455 [b]	417 [ab]	NS

Note: [a)] See Table 1.

[b)] Frequency of use of 8 individual feed troughs.

[abc]: Figures without a common letter are statistically different (P<.05).

As much as 2 m/sec. wind is said to be beneficial to milk yield in Holsteins at 26.7 ℃.[7] On the other hand, intermittent winds from 1.0-1.3 m/sec. (1.5 m/sec. at most) seem to be suitable for dairy cows[12]. The setting of 1.5-1.7/sec. around the shoulders when cows lie down was made on the basis of this information. The 0.2-0.3 m/sec. wind on the stall floor did not cause a scattering of particles of separated manure compost including sawdust that was used for bedding.

Longer lying time in the stalls and higher frequency of stall use were found in Period 2 with the localized air flowing system compared with Period 3 with no system in the same hot environment. This indicates that this system contributes to the improvement of stall use and the reduction of heat stress by changing the microclimate in the stalls.

However, it is thought that this system also shows the partial effect of improvement in the hot environment, from the decreases in daily lying time and total stall use time and increases in respiration rates and rectal temperatures in Period 2 when air temperature was higher under the same localized air flow conditions as in Period 1. Increasing the volume of air from blast pipes, or using large ventilating fans concurrently are recommended in order to alleviate heat stress more effectively.

In FS barns, the adjustment of the thermal environment is based on natural ventilation, but use of forced ventilation toward the floors using large ventilating fans is increasing, since a stable and favorable thermal environment cannot be adjusted only by natural ventilation. These fans are often installed above alleys in order to promote excreta drying in the alleys and reduce heat stress besides the forced ventilation, which suggests the possibility that may cause decreases in the total stall use and lower the popularity of some stalls. Although further studies to confirm this possibility are required, the use of this system might compensate for these faults, because this system may level out the cooling microclimate of stalls due to the constant volume of air streams. The localized air flowing system for stalls designed in this paper seems to control the entire thermal environment of the FS barn and reduce heat stress effectively by concurrent use of large ventilating fans toward the floor over the alleys.

This system might also offer beneficial effects from decreasing occurrences of cows lying in the alleys and lessening the risk of hoof diseases, because of behavioral changes such as increases in lying time in the stalls and decreases in standing and migrating time in the alleys. Further studies are needed to clarify these possibilities.

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暑熱時の泌乳牛の行動に及ぼすフリーストール局所送風の影響

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摘　要

フリーストール（FS）飼養の乳牛における暑熱時の採食量や乳生産量の低下を軽減し，牛床の利用性を高めるために，8床のFSペンに飼養するホルスタイン種泌乳牛7頭を用い，牛床に局所送風を行う管を設置し，24時間連続の局所送風が暑熱時の乳牛の行動などに及ぼす影響を検討した。局所送風は，牛床のネックレール上に設置した塩化ビニール管（床上110cm）の吹き出し口を通して，横臥時の牛体に対して配風される機構（特許出願中，特願2001-23661）を特徴とする。調査期間は梅雨明け（7月23日）を挟み7月14日～8月3日とし，3期各3日間の観察を行った。第一期は梅雨の局所送風期（平均気温22.6℃），第二期は梅雨明け後の局所送風期（同26.3℃），第三期は梅雨明け後の無送風期（同26.8℃）とした。第二期は第一期に比べ，呼吸数，直腸温が有意に（$P<.05$）上昇したが，ウシの採食量，乳量，体重に差は認められなかった。第二期と第三期との間には，気温，直腸温に差はなかったが，第三期では，呼吸数が有意に（$P<.05$）上昇し，乳量，体重が有意に（$P<.05$）低下した。牛床での横臥時間，同総利用時間は，送風期でも第二期のように高温になると有意に低下し，無送風期の第3期はさらに有意に（$P<.05$）低下した。また無送風期は採食時間が低下傾向を示す一方，通路の佇立・移動時間が有意に（$P<.05$）増加した。

キーワード：局所送風，フリーストール，横臥行動，泌乳牛，暑熱環境